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OF THE

AMERICAN WELDING SOCIETY

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American Welding Society

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AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

Volume 5 December, 1926 Number 12

FALL MEETING OF AMERICAN WELDING SOCIETY

The sixth Fall Meeting of the Society and the greatest in its history was held in Buffalo on November 16 to 19. As a background to this meeting there was arranged a remarkable welding and cutting exposition.

The exposition itself served as an educational feature for a registered attendance of some fifteen hundred people. The exposition included working exhibits of the latest developments of welding operations by all processes and also of the cutting of metals. In addition, there was a display of a large variety of products fabricated by one or more of the welding processes. The importance of the welding industry was clearly demonstrated by these exhibitions. Nearly all the important manufacturers of welding supplies had one or more booths in the exhibition hall.

The technical sessions started on Wednesday morning, November 17, with an overflow meeting, which packed all the available space and assured the success of the sixth fall meeting from the start. The first technical session was devoted to papers on applications of welding in the railroad field. All the papers presented at the Fall Meeting were printed in advance in the October issue of the Journal. This arrangement allowed greater time for the discussion of the papers by the members. Several hundred people were in attendance at the various technical sessions of the Society.

On Wednesday afternoon, there was presented a review of some of the recent researches on the application of welding to steel structures. This included prepared papers by Mr. A. M. Candy of the Westinghouse Electric and Mfg. Co., and H. S. Moss of the Linde Air Products Co. In addition, Prof. H. L. Whittemore of the Bureau of Standards, presented a summary of some tests made on a welded girder. Mr. W. Spraragen presented a review of some large welded structurers in existence in other countries, principally in Australia.

The meeting of the newly organized Structural Steel Welding Committee was held, Wednesday evening, at the Hotel Statler and was attended by a majority of the members of the Committee. Sub-committees were appointed on special subjects and it is expected that very shortly a comprehensive program of investigations will be started in this field.

One of the most important sessions of the Fall Meeting program was held Thursday morning, which was devoted to a symposium on "Welding Science in the Engineer Curriculum of Universities." Seven universities presented prepared papers which were discussed by those present.

The Welding Wire Specifications Committee held an open meeting on Thursday afternoon, at which about three hundred people were in attendance. Mr. C. A. McCune, Chairman of the Committee, presented a review of a large series of tests made on samples of good and bad welding wire collected from various parts of the country. It is expected that this report will be available in the near future for publication in the Journal of the Society. The meeting of the Welding Wire Specifications Committee was followed by a meeting of the American Bureau of Welding with Director C. A. Adams, presiding. The session was given over to reports of progress made by the Rail Joint and Structural Steel Committees. Prepared reports were presented on possible fundamental investigations, including "Fatigue Testing," by Prof. H. L. Whittemore, a progress report of the San Francisco sub-committee on test of welds to be subjected to high temperatures, non-destructive tests for welds and a comprehensive summary of possible fundamental investigations in the arc welding field by Mr. H. M. Hobart. A tentative program of investigations of the joint committee on Pressure Vessels of the A. S. M. E. and the American Bureau

of Welding was reviewed and discussed.

The annual Fall Banquet was held Thursday evening at the Hotel Statler. An outstanding feature of this occasion and, in fact, the entire Fall Meeting program was the presence of the ladies. Under the direction of Mr. H. R. Swartley as Toast Master the speeches were short, exceeding humorous and enjoyed by all those present. Professional entertainment and dancing, together with an excellent menu, served to make this occasion one that will be long remembered by all those who attended.

The technical session for Friday morning was devoted to two papers on "Welding in a Gaseous Atmosphere" by Mr. P. P. Alexander and R. A. Weinman of the General Electric Co. A meeting of the Board of Directors was held at the Hotel Statler, at the same time. It was followed by a luncheon given by the President at the Buffalo Athletic Club, which was attended by Vice-Presidents and Section Representatives. Plans were discussed at this luncheon for stimulating activities in various sections of the Society.

A fitting close for the Fall Meeting was the inspection trip to Niagara Falls. Three huge buses served to convey the members from the Auditorium to the Niagara Falls power house where members were conducted through this gigantic power station and given an opportunity to see the working of one of the largest modern hydroelectric stations of the world. The trip continued to the Falls and the grandeur of this marvelous natural wonder was enhanced by a special illumination and a heavy snow fall. From the falls the party was taken to the new Niagara Hotel where they were served an excellent dinner, returning to the Hotel Statler in Buffalo about 10 p. m.

Special entertainment was provided for the ladies who were in charge of Mrs. R. Siemer, as hostess. This entertainment included tea, an inspection trip through the city of Buffalo, in addition to the dinner, dance and the inspection trip to the Falls.

DIRECTORS MEETING

A Meeting of the Board of Directors was held on Friday, November 19, at the Hotel Statler in connection with the Annual Fall Meeting of the American Welding Society. The calendar of business included reviews by the Executive, Finance, Meetings and Papers, Membership and By-laws Committees as well as of the American Bureau of Welding.

Mr. G. O. Wilson of the Standard Oil Company, was nominated as vice-president of the Pacific Coast Division to take the place of Mr. N. A. Wright, who has resigned.

Consideration was given to the appointment of a Technical Secretary of the Society. The Board, at the recommendation of the Finance Committee, voted to purchase for a sum not exceeding $200, the International Welding and Cutting Exposition, Inc. The Board agreed to the appointment of a permanent organization to handle all exhibitions in connection with future Fall Meetings.

Detroit was selected as the place for the next Fall Meeting of the Society.

THE FUTURE OF WELDING

(*Editorial appearing in the Nov.* 30, 1926, *issue of Power*)

Welding is an infant industry. Its rapid expansion is due to the versatility of the process, supported by campaigns of research and education. With the makers progressive and the users open minded, welding will expand as fast as it can make good in new applications. Already the applications are distributed as broadly as is the use of metal in industry.

In the power field alone, welding is now well established for the fabrication of low-pressure steam and water lines, atmospheric-relief lines, breechings, bunkers, tanks, etc., and for repairs to engines, stokers, coal-and-ash-handling systems, and so on.

In the field of high-pressure piping welding may be said to have gained a good toe-hold. From a start where the weld was used merely as a seal, it is now frequently used to carry the actual load of high pressures.

Code restrictions and misgivings of engineers have retarded the application of welding to pressure vessels. It is to be hoped that tests to be made under the joint auspices of the American Welding Society and the Boiler Code Committee of the A.S.M.E. will make it possible for welding enthusiasts and conservative users to find some middle ground on which to compromise their present differences of opinion. Meanwhile, it is well to remember that pressure vessels are just one of many fields for welding.

FALL MEETING BANQUET, BUFFALO, NOVEMBER, 1926

ACTIVITIES OF THE AMERICAN BUREAU OF WELDING

During the coming year the American Bureau of Welding is planning to launch several large cooperative investigations in the welding field.

Structural Steel

A committee is being appointed to cooperate with the American Institute of Steel Construction, steel companies, fabricators and others in the conduct of a comprehensive investigation which will secure reliable and authentic data on the fundamental units of weld strengths for the different kinds of stresses encountered in structural joints and to determine the ability of welded connections to resist such stresses in completed, full size structural members.

Investigational Program

The first thing the committee will do will be to make an exhaustive review of existing information and tests in this field. A series of test specimens will be prepared by fabricating plants in various parts of the country in accordance with prepared specifications. These specimens will be designed to yield information as to the fundamental units of weld strengths for the different kinds of stresses encountered in structural joints, such as tension, compression and shear, when these joints are made under various conditions. The variables may be the type of weld whether lap, butt or tee, the process of welding and whether hand or automatic welding is to be used. Full size structural members will later be made up to determine the distribution of stresses in a welded frame and the ability of the welded connections to resist such stresses.

Importance of the Work

During the last two years, great progress has been made in extending the use of welding in the fabrication of structural steel. A number of important welded structures are already in existence. Investigations often made by individual companies are uncoordinated and incomplete and for the most part do not yield the fundamental design data needed by structural engineers. The problem is to secure information which will allow welding to be used in this field where it is economical. As confidence is gained and personnel of fabricating companies become experienced, greater extensions will be made.

Pressure Vessels

1. *Object:* To secure additional data and information now lacking which will assist designing engineers and tank manufacturers in fabricating safe and economical welded pressure vessels and to supply information as to the A. S. M. E. Boiler Code Committee on the welding of unfired pressure vessels. The results of these tests will extend and supplement the information secured from a preliminary investigation on welded pressure vessels made by the bureau some three years ago.

2. *Importance of the Work:* The present code of the A. S. M. E. is unduly restrictive and incomplete in the eyes of the welding fraternity, so far as it relates to welding. On the other hand, regulatory bodies charged with the responsibility of safety are reluctant to go any further in drawing up codes than the authentic information which they have available will permit them. Those familiar with the situation agree that we need the information which will be secured as a result of the tests outlined in the program.

3. *Testing Work:* The testing work will be done by the Bureau of Standards and university laboratories under the direction of the Joint Pressure Vessel Committee of the American Society of Mechanical Engineers and the American Bureau of Welding.

4. *Funds and Materials:* Cash funds will be raised from the interested industries. National Research Council will act as treasurer. These funds will be used for supplying the Bureau of Standards with some test assistants, apparatus, testing facilities, some traveling expenses of professorial members and publication of the results. Tanks, materials and test specimens must also be furnished by the interested industries. It is estimated that about fifteen thousand dollars per year for two years will be needed for this work.

5. *Test of Welded Tanks:* A large number of tanks will be tested to destruction by applying hydrostatic pressure and hammering near the welds. Information will thus be secured as to the action of various designs of heads, joints and methods of welding under pressure. Some of the types of tanks to be tested are as follows:

(1) Lap welded seam.
(2) Reinforced strap seams.
(3) Single vee tanks, automatically welded.

(4) Single vee tanks, hand welded on one side.
(5) Single vee tanks, hand welded, with slight "reinforcing weld" on the inside.
(6) Electric compression induction welds.
(7) Riveted tanks.
(8) Riveted welded tanks.
(9) Carbon arc.
(10) Large size tanks, and
(11) Tanks designed for heavy pressures.

6. *Fatigue Tests on Wide Specimens:* Very little information exists as to the behavior of welded and riveted joints under alternating stresses. The Boiler Code Committee is particularly anxious to secure information on this subject. Fatigue tests are expensive to make in that each specimen takes a long time to test.

7. *Breathing Tests for Tanks:* The Boiler Code Committee of the A. S. M. E. have also requested that information be secured on the behavior of welded tanks under varying internal pressures such as to cause a breathing action in the tanks. It is expected that a number of tanks will be tested to destruction in this way and comparative tests also made on riveted tanks.

Fundamental Investigation

Object: To coordinate the information that we now have with respect to the exact phenomena that are encountered when welds are made, and to attack some of the important fundamental problems of that nature that are still unsolved.

Typical Problems: Typical problems needing solution are:

(1) What is the action of welded joints under various stresses when subjected to high temperatures?

(2) What unit stress may be used in designing welded joints of various types when subjected to alternating stresses?

(3) Non-destructive tests for welds.

(4) What can be done in heat treatment and forging of welds?

(5) What effect have flux coverings, coated and other special wires in preventing contamination of the metal while it is being transferred from the welding wire to the work?

(6) What is the effect of the chemical composition of the welding wire on the rate of transference of metal?

(7) What is the effect of the grain structure of the wire on its suitability for use in the form of electrodes?

(8) Why can some kinds of good welding wire be made bad by polishing the surface, or by pickling?

(9) Why is it possible to transfer carbon and manganese across the arc with certain wires and not with others.

(10) Effect of heat of welding on adjacent metal.

(11) What are conditions giving notably good welds as regards ductility and non-porosity?

Importance of Work: The importance of fundamental investigations cannot be over-emphasized. It forms the foundation for the sound development of the industry. Knowledge of the reason "why" will eliminate much of the "cut" and "try" methods. It will also make possible extension of the use of welding and open up new fields of application. Investigations of this sort call for the highest scientific talent available.

SECTION ACTIVITIES

New York

The December meeting of the New York Section will be held on the 21st. A symposium on Pipe Welding has been arranged for this meeting. The following papers will be presented: "Arc Welded Steel Pipe for High Pressure Mains for New York City," by William Schenstrom, Electric Welding Co. of America; "Pipe Welding from the Oxy-Acetylene Viewpoint," by LeRoy Edwards, Air Reduction Sales Company; "Welding of Pipe Line for Mokelumne River Project," by J. F. Lincoln, vice-president, Lincoln Electric Company.

The papers will be illustrated by lantern slides and ample opportunity provided for discussion.

The January meeting has been arranged as a joint session with the local section of the American Society of Mechanical Engineers. The meeting will be held on Jan. 4. The following papers are scheduled: "Replacing Castings by Welded Structural Shapes in Machine Design," by W. L. Warner, industrial engineering department, General Electric Co.; "Design of Dished Heads for Pressure Vessels," by Messrs. S. W. Miller and A. B. Kinzell, Union Carbide and Carbon

Research Laboratories, Inc., and Messrs. H. E. Rockefeller and T. W. Greene, Linde Air Products Co.

Western New York

The Western New York Section held its December meeting on the 14th. In accordance with the President's suggestion, the meeting was arranged as a joint meeting with the Engineering Society of Buffalo and two local sections, namely, the American Society of Civil Engineers and the American Society of Mechanical Engineers.

About 100 members and their guests were present. Mr. G. J. Walker, research and development engineer of the Air Reduction Sales Co., presented a paper on cutting of metals and particularly cast iron with the oxy-acetylene torch. The paper included the theory of cutting and the value of cast iron cutting. The cutting of steel for various purposes was also covered. After the talk, Mr. Walker showed a series of interesting slides illustrating various applications and diagraming the methods of manipulating the torch. The moving picture, "Oxygen, the Wonder Worker," was also shown.

Chicago

The December meeting was held on the 3rd in the rooms of the Western Society of Engineers. L. E. Everett, of the Nugent Steel Casting Company, presented a paper on "Removal of Risers in the Steel Foundry." This paper gave some very interesting data and information pertaining to the common practice in the removal of risers in the modern steel foundry.

Cleveland

The November meeting of the Section was held on the 30th as a joint meeting with the Cleveland Engineering Society. The meeting was held in the Y. M. C. A. Trade School, with about 150 in attendance. The paper of the evening was "Metal Spraying by the Schoop Process." The metal is melted by use of the oxy-acetylene flame. This process is used in building up cast iron parts and in reclaiming cracked cylinder blocks.

Northern New York

The Northern New York Section held a joint meeting with the Schenectady Local Section of the American Society of Mechanical Engineers in the Edison Club Hall, Schenectady, Nov. 30.

Mr. A. M. Candy of the Westinghouse Electric and Manufacturing Company gave an illustrated lecture on "Arc Welding Structural Steel." The tests conducted at Carnegie Tech. last summer on test specimens welded by Westinghouse Company were described in detail.

A set of slides was also shown of the five-story building now being erected by the Westinghouse Company at Sharon, Pa.

Those in attendance agreed that this was one of the most interesting sessions held by the Section.

Pittsburgh

A meeting of the Pittsburgh Section was scheduled for Friday, Dec. 17. Mr. E. Wanamaker, electrical engineer, Chicago, Rock Island and Pacific Railway Company, Chicago, Ill., will present a paper on the subject, "Welding, Personnel and Organizations."

San Francisco

The San Francisco Section held a meeting on Nov. 19. Mr. Wm. Aldrich of the Metal & Thermit Corporation delivered a paper on "Thermit Welding." His remarks were illustrated with lantern slides and moving pictures. Mr. Saunders, chairman of the membership committee, outlined some plans for increasing the Section's membership. Mr. K. V. Laird, chairman of the subcommittee on investigations of welds to be subjected to high temperatures, gave a very interesting progress report.

The December meeting was scheduled for the 17th. Mr. R. M. Lutz, chief engineer, Pacific Rolling Mill Company, San Francisco, presented a paper on "The Design and Erection of a Welded Structural Shop." Mr. J. C. Bennett, who represented the Section at the fall meeting of the National Society at Buffalo, was scheduled to give a report of the convention.

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Instruction in Welding at Lehigh University*

By F. V. Larkin†

Two years ago some of us charged with the responsibility of directing the Engineering Curricula at Lehigh University, reached the conclusion that the time had arrived when we should incorporate instruction in welding into our engineering courses at Lehigh University. This fact was forcibly brought to our attention at a meeting of the Lehigh Valley Chapter of the American Society for Steel Treating, who devoted an afternoon and evening to a series of demonstrations and papers on the general subject of cutting and welding.

The meeting was held at the Exhibition Building of the Bethlehem Steel Company. The afternoon was given to demonstrations of various types of cutting and welding operations. In the evening moving pictures of the art were exhibited and a number of technical papers presented. Six companies took part, each demonstrating its equipment and each contributing to the technical discussion. The interest manifested in this meeting, measured by the attendance, was splendid. Our junior and senior students in Mechanical Engineering attended the meeting in lieu of an afternoon laboratory exercise. Their attention and their questions indicated two things: first, that they were genuinely curious and interested; and second, that as engineers and operators of the future, they are the type of men who must carry on the development and utilization of the art.

Following the meeting, arrangements were made with one company whereby the company made the university a permanent loan of cutting and welding equipment on the condition, (a) that the university would send one of its mechanicians to their factory for a period of instruction, and (b) that the university would in some manner bring the art with its ramifications and possibilities before all the senior engineering students at the university each year.

The first condition was easy to meet. Our laboratory mechanician gladly embraced the opportunity to make the out-of-town jaunt, because it partook of the nature of a vacation, because it enhanced his personal prestige, and because it enabled him to add to his general capabilities and usefulness. The second condition was easier to make than to put into operation. We have eight different engineering curricula at Lehigh. A number of them take the same laboratory courses, but in no case do all of them take any one laboratory course. Therefore it became evident that some special arrangement must be made in order that all senior engineering students at the university be given some work per-

*Presented at Annual Fall Meeting, American Welding Society in Buffalo.

†Head of Mechanical Engineering Dept., Lehigh University.

taining to the art of welding. This fact, together with certain other features concerning laboratory personnel, space and equipment, led us to meet the situation by scheduling what we called a "welding symposium," covering an afternoon and evening, attendance at which was required by all senior engineering students. Conflicting assignments were either postponed or excused, and a report was required from each student. I might digress here to say that while the symposium was gratifying and satisfactory to a high degree, the students referring to it in their humorous recitals dubbed it the "Welding Imposition."

A symposium having thus been decided upon, it was announced by an official proclamation signed by the president of the university and a committee selected to make the necessary arrangements.

The following program was established, printed and mailed to the membership of the Engineers' Club of the Lehigh Valley, approximately 550 members.

LEHIGH UNIVERSITY

Cordially Invites Engineers and Others Interested to Visit the University
Tuesday, March 23,
and attend a
SYMPOSIUM ON WELDING

Afternoon Program

1 *P. M.—Physics Lecture Room*
Lecture illustrated by Motion Pictures on Welding and Cutting, by Professor Bradley Stoughton, Professor Metallurgy, Lehigh University.
Lecture on Oxy-Acetylene Welding, by Mr. E. E. Thum, Engineer of Linde Air Products Co.

2–4 *P. M.—Fritz Engineering Laboratory*
Demonstration of Cutting and Welding, under the direction of Mr. C. A. Bradburn of the Oxweld Acetylene Co.

Evening Program

8 *P. M.—Physics Lecture Room*
Mr. E. E. Thum of the Linde Air Products Co., will present new and unpublished data on the design and strength of Welded Joints.
The Engineers' Club of the Lehigh Valley urges its members of the National Engineering Societies to accept this invitation.

In regard to the demonstrations, I may say that they were announced so that the students could get the data, executed by an expert welder, and pulled in a testing machine by one of the laboratory professors, who announced the results for the students. I note that my memoranda written for file following the symposium, indicates a delay in the laboratory and recommends that the test samples be prepared ahead of time, together with a chart showing the data peculiar to each demonstration. This to avoid the time lost in giving data to students at the time of the demonstration.

As indicated before, we consider the symposium a success to

so high a degree as to warrant our procedure along the two lines indicated:

(a) We consider it wise to have our professor of Machine Design bring up to date the status of welded joints in engineering construction and make for the students a comparison of its utility and dependability in practice, as accepted by the engineering societies. We, likewise, plan to extend the scope of the symposium to include all processes of welding, with demonstration of methods and comparison as far as possible with laboratory tests, of the welded and unwelded pieces.

(b) Looking still farther ahead, we have hopes of making this symposium an annual event at which all manufacturers of welding equipment may find it worth while to exhibit and demonstrate their equipment, and to which industrialists in the vicinity of the university may find it worth while to come for a discussion of the details and the progress of the art.

In conclusion may I say that while we hope that our undertaking in this matter may be judged by our aspirations rather than by our present accomplishment, we have made a start. We feel that the plan affords an opportunity for a four-fold service:

1. To acquaint the students with the status of the art.
2. To furnish a common worthwhile meeting ground for manufacturer and user.
3. To afford the university an opportunity to put its facilities at the service of the industries.
4. To afford the students contact with an important growing phase of engineering development.

Oxidation of the Arc Crater*

BY P. ALEXANDER†

The oxidation and nitrogenation of the molten iron in the crater of the welding arc have been studied by many investigators, and the importance of these reactions is well understood.

The subject of his paper is to discuss the same matter. However the importance of the oxidation reaction is considered here from another point of view.

The present endeavors by many investigators to produce a still more ductile and sound weld bring a special interest in the study of the chemical reactions taking place in the crater of the arc. We know from analysis of the arc deposited metal that oxygen and nitrogen combine directly or through some intermediate stages

*Presented before the Fall Meeting, American Welding Society, Buffalo, N. Y., November, 1926.

†Research Engineer, Thomson Research Lab., General Electric Company.

with the molten iron. The deleterious influence of oxides and nitrides is well known and need not be discussed.

The question of interest is what influence the oxidation reaction exercises on the porosity of the weld; in other words, what is the relation of the oxidation of the surface of the crater to the number of gas pockets in the solidifying metal?

The molten steel in the crater of the arc absorbs large amounts of the gases surrounding the arc. All gases are soluble in molten steel to a certain degree. Hydrogen and carbon monoxide are probably the most soluble ones. It is understood that the solubility of gases in molten metal is a function of their molecular weight and should be decreasing with their density. Yet direct observations fail to show great distinction even between gases of such widely different densities as argon and helium.

It may be inferred that in the practical applications of welding all gases may be considered as soluble to a very great extent. Solubility of the gases in the steel, copper and other metals used in welding is a function of the temperature. At the boiling point metals are practically free from dissolved gases. Then as the temperature of the metal drops down the solubility at first rapidly increases to a maximum, somewhere half way between the boiling and melting points of the metal considered. The further drop in the temperature is followed by a slight decrease in solubility until the freezing point is reached. At the moment of the change of liquid state into solid state the solubility drops very abruptly. The result of this abrupt change in solubilities is that during the freezing of the metal very large volumes of gases are liberated in the mass of the metal, and if not allowed to escape are trapped and form numerous blow holes.

In the manufacture of steel castings or crucible steel, various methods are employed to insure a free escape of the evolved gases. The conditions during solidification of arc deposited metal are different from those met in steel manufacturing. The freezing of arc deposited metal is so rapid that unless the freezing is retarded to insure the escape of the precipitated gases the weld metal will be very porous.

When the welding is done in air the molten metal in the arc crater absorbs very large volumes of nitrogen from the air which is expelled during the solidification of the metal. It is this efficient mechanism of evolution of the precipitated gas which deserves a careful study. To reveal the mechanism of the gas evolution a series of experiments were conducted on the deposition of the metal in oxidizing, neutral and reducing atmospheres.

The first close examination of the large craters of powerful welding arcs burning in air showed that the metal is boiling near the foot of the arc core. Outside of that region there is a concentric belt in which the molten metal is comparatively quiet. But the cooler parts of the crater and especially the regions next to

the solidifying edge of the molten pool are in a state of continuous agitation. A large number of small gas bubbles are continually rising and escaping from the surface of the molten metal. At the same time an iron oxide continually forming on the surface of the molten metal floats like a layer of slag. Of course part of that oxide goes into solution as FeO. The rest of the oxide left on the surface is further oxidized during the solidification of the metal and forms a layer of Ferroso ferric oxide.

The oxidation reaction is a source of very large amounts of additional heat. One gram of iron when oxidized to form Fe_3O_4 will produce 1616 calories of heat. Calculations show that if this amount of heat be absorbed by the thin top layer of the cooling metal, the temperature of that layer will be raised by several hundred degrees. In other words, the amount of heat produced by the oxidation of the top layer of the molten iron is sufficient to retard the freezing of this layer and keep the surface in the molten state until the rest of the weld has passed into the solid state. This free surface allows all the evolving gases to escape freely from the weld and leave it free from blow holes.

To verify this assumption a series of experiments were made on the deposition of metal in an atmosphere of pure argon and the mixtures of that gas with different amounts of oxygen. The welds produced with pure iron electrodes in pure argon are quite porous. Half of one per cent of oxygen added to argon is noticeable by a slight oxidation of the surface of the weld.

When the amount of oxygen is increased to form 6 per cent of the atmosphere surrounding the arc the oxidation of the surface of the crater is quite pronounced and the weld is more or less free from blow holes. Twenty per cent of oxygen gives conditions identical to those observed when welding is done in air and the deposited metal is entirely free from blow holes.

Observations of the craters of arcs maintained in other gases are quite in accord with the above statements and lead to the conclusion that oxidation of the surface of the arc crater is the determining factor in the free escape of the evolved gases. It is oxygen which is responsible for the sound welds produced in air. Of course this freedom from gas pockets is obtained at a cost of a very high oxidation of the deposited metal, which makes it unsound in other respects.

When it is desired to produce a weld of high ductility, oxygen must be kept away from the crater either by protecting its surface with an exceptionally heavy layer of fluxes or by surrounding the arc with hydrogen or other suitable gaseous media. As the top layer is no longer the seat of production of additional heat it sometimes solidifies simultaneously with the rest of the deposited metal, with the result that a part of the evolving gases is trapped. From the foregoing statement it can be seen that as long as we desire to prevent oxidation of the weld we are confronted with the problem of the free escape of the gases.

As has been already stated, it may be inferred that in practical work on arc welding all gases can be considered as very soluble. Therefore, the problem of production of nonporous welds consists in the efficient method of expulsion of the evolving gases. As has been shown above, this is being taken care of by the oxidation reaction when the welding is done in air. In the more careful methods of welding in reducing and neutral atmospheres or when the crater is fully protected by a heavy layer of fluxes, other means should be provided to retard the solidification of the surface layer.

In the atomic hydrogen process the oxidation reaction is replaced by the recombination of the atomic hydrogen into the molecular state. In that process the adopted technic is such that the solidifying edge of the molten pool is continually swept by the atomic hydrogen blown off the arc. When the atomic hydrogen comes in contact with the iron it recombines into the molecular state, and therefore replaces the oxidation reaction present in other methods of welding.

The Shielded Arc process, as has been previously described, is used for carbon arc and metallic arc welding. In both cases the arc is protected or shielded from atmospheric oxygen by a gaseous screen of hydrogen, water gas or other gaseous media. Here the oxidation reaction is entirely suppressed, but the solidification of the surface layer may be retarded by direct radiations from the arc, careful control of the speed of travel, and (or) motion of the tip of the electrode.

While apparatus for practising the Shielded Arc process is not yet upon the market this process will soon find its place of usefulness alongside other welding processes in the practical fields of application.

Discussion on Autogenously and Electrically Welded Boilers and Containers*

BY WILLIAM SCHENSTROM†

I have studied carefully the paper by E. Hohn on "Welded Boilers and Containers." It should help strengthen confidence in the welded joint in pressure vessels.

Of special interest to me is the lap welded joint referred to in Figs. 33 and 34. Is the author correct in his stand that the lap weld is inferior? "Originally tough material is fused out and replaced by brittle welding material." By inference I take it that he means that the butt welded single or double V weld is not similar in that respect—if, indeed, it is a fact in the case of the lapweld. In Fig. 1, below, of a lapweld the weakest point may be at the extreme toe of the welds, cross sections A and A. Between these

*Printed in June, 1926, issue, JOURNAL of the A. W. S.
†Welding Engineer.

points there is the original cross section of plate plus—clear up to double plate thickness. In Figs. 2 and 3, it seems to me that the same condition prevails exactly at points B B and C C as in A A. If there is a notch in one instance there is as much likelihood of one in the others. Here the likeness ends: In Fig. 1 say,

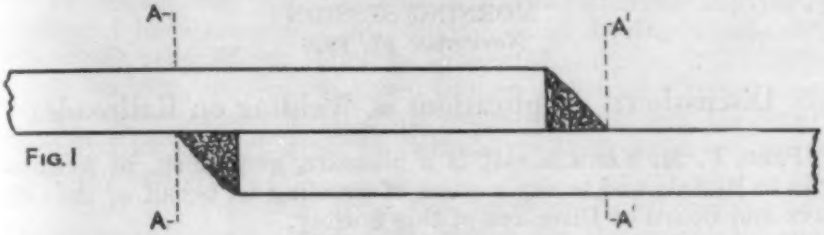

FIG. 1

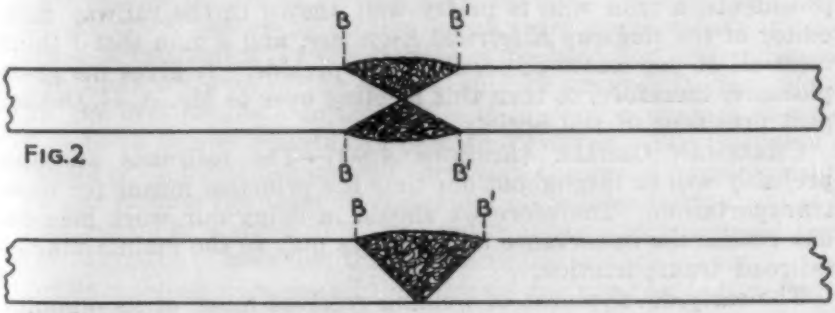

FIG. 2

FIG. 3

that the two pieces of plate were welded together only at A'A'. We would, if we pulled a test piece with a tangential pull—so as to eliminate the composite effect due to the shape—have an adhesive cross section of welding on each of the two plates equal to the thickness of the plates, given sufficient bulge in middle of weld. I feel that this joint must be given full value along with any other welded joint, of two plates with similar adhesive surface. This is for a weld from one side only. Now take a joint welded from both sides. The welds act as clamps for each other. Add the two welds together and you get very much more than 100 per cent strength, with a cross section at all points between the two extreme outside ends of joints, in excess of the cross section of one plate's thickness. The bending on outside lap referred to by Mr. Hohn, I cannot understand. If tank is properly made into a cylinder, plates lapped and lap is free to move, while joint is made—the tangential pull should be evenly distributed between the two welds making the joint. This should, therefore, be the strongest joint irrespective of thickness—up to thicknesses that cannot readily be worked into laps.

I have never seen in test or practice where a double lap joint broke in the joint.

Sixth Fall Meeting of American Welding Society at the Broadway Auditorium, Buffalo, N. Y.

MORNING SESSION
November 17, 1926

Discussion: Applications of Welding on Railroads

PRES. F. M. FARMER.—It is a pleasure, gentlemen, to welcome you to Buffalo and to say a word of greeting on behalf of the Officers and Board of Directors of this Society.

The first session, of course, is to be devoted to the discussion of the application of welding to the railway field. One of our past presidents, a man who is pretty well known in the railway field, editor of the *Railway Electrical Engineer,* and a man that I think most all of you know personally, will preside. It gives me great pleasure, therefore, to turn this meeting over to Mr. A. G. Oehler, past president of the Society.

CHAIRMAN OEHLER (*Railway Age*).—The railroads are and probably will be throughout our time the principal means for mass transportation. Therefore we should in doing our work here today realize the importance that welders play in the maintaining of railroad transportation.

The early development of welding received much of its stimulus from the railroads. They needed welding badly and they fulfilled that need by developing welding. That led to a more or less peculiar situation. There were men on different railroads and in different industries who were familiar with a certain process of welding. The result was that the one railroad would adopt one kind of welding to the exclusion of others, and vice versa.

Now the art has developed to another stage. We all know that to use welding to its fullest advantage the welding supervisor or whoever is responsible for the work, must know welding as an engineering subject. He must be able carefully to weigh the advantages of the different processes.

The first speaker upon today's program I feel a bond of sympathy for. He is employed by one of the most progressive railroads in the country which at one time I had the privilege of working for, namely, the Northern Pacific. He is a man who understands welding from the point of view of the welding engineer.

I take great pleasure in introducing Mr. G. H. Gjertsen, who will talk on "Welding of Locomotive Parts by the Oxyacetylene, Electric and Thermit Processes."

MR. G. H. GJERTSEN (*Northern Pacific Railway Company*).—I appreciate very much the opportunity of preparing this paper and reading it before you here today, and while the things I have

to say in my paper and the pictures I have to show may not be anything new to the most of you, yet it might bring some ideas to those who are less familiar with the railroad work and what the railroads are doing. I will read the paper first. (Reads paper.)*

In connection with the automatic operation in the railroad shops, I have some data on building up of driving wheel centers in which some of you might be interested.

In building up driving wheel centers and trailer wheel centers with the automatic electric arc welding equipment the work is handled in a wheel lathe, the wheels revolving as in an ordinary turning operation.

Where much of this work is to be done, it is advisable to set aside an old wheel lathe for this purpose as the speed of the lathe must be cut down to about three revolutions per hour to successfully handle the largest driving wheel centers. This can, of course, also be accomplished by putting up an extra countershaft or other speed arrangement so the lathe can be used for both purposes. The surface travel of the work should be about 9 in. per minute for the best results. In using a 3/16-in, wire a surface speed of 6 in. to 12 in. per minute can be used, however. The thickness of the layer of metal put on will vary with the speed. In covering 6 in. per minute the layer of metal put on will be twice the size of that put on at a speed of 12 in., and in using a slower speed there is less chance of breaking the arc where the surface is rough.

The welding wire used in automatic arc welding is supplied in coils shipped on spools, approximate weight of wire on each spool being 250 lb.

The type of driving wheels shown on the photograph are hollowed out or recessed in the center; the outside surfaces of the face of the wheel are first built up with the automatic equipment and the bridges in the center are filled in by hand operation. One operator operates both automatic heads, and on 62-in. wheels of this type about 5 hours is required for the automatic operation where a layer of metal about 3/16 in. thick is put on the surface. The filling in of the bridges is done by hand and requires about 3 hours on each wheel. The hand work is done by connecting to the same machines and an additional welder from the floor may be used in filling in the bridges to speed up the work, one welder working on each wheel if this is desired. Where the wheel has a solid face and can be finished with the automatic, better time can be made.

The photograph showing the automatic equipment set up for building up guides shows one set of equipment complete which includes one motor generator set, one control panel and one automatic welding head.

The automatic welding head is mounted on the carriage of the

*Paper published in the Oct., 1926 issue, Journal A. W. S.

lathe in such a way that it can be raised and lowered to accommodate the work. This arrangement can be used for any flat work, also for work that is round and can be revolved on the centers of the lathe or in the chuck.

We are using the equipment to very good advantage, especially in building up worn guides.

The automatic equipment is very sensitive and cannot be operated successfully from a line where there is interference from heavy loads cutting in. A sudden fluctuation of current has a tendency to break the arc when the machine is working to its capacity and interferes with the smoothness of the work.

In regard to the capacity of the equipment may state that where 3/16-in. wire is used approximately 250 amp. current is required, and if a separate motor generator set is used for each automatic head it should be of 300 amp. capacity.

The selection of the operator assigned to handle this equipment will have much to do with its success as it requires a man with ingenuity as well as willingness to apply himself in order that the best results may be obtained.

We have a great deal to learn in automatic equipment. In the year that we have been experimenting with the equipment we have been very pleased with the success and have made improvements. We have many improvements to make, but it is working out very nicely and doing everything that we expected. I think that there is a great field for the automatic electric equipment in railroad work. It requires a little engineering and a little ingenuity to rig up to handle the work, but after you get rigged up it certainly pays to apply those arrangements.

A MEMBER.—Do you know the cost of the amount of metal deposited, the current, labor and material?

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—I have some cost data that I obtained in the first week I had the equipment. The total cost of building up one set of driving wheels is from $16 to $18. The last figures I got from South Tacoma was between $17 and $18, I think, the total cost of building up the driving wheels and turning them down.

A MEMBER.—Is that based on one operation of two heads?

MR. G. H. GJERSTEN.—Yes.

A MEMBER.—Do you know how much material was used?

MR. G. H. GJERSTEN.—About 30 lb. on each wheel.

A MEMBER.—Isn't it necessary to have an operator with that machine to watch it?

MR. G. H. GJERSTEN.—Absolutely.

A MEMBER.—Is that included in the cost?

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—That is the total cost. An operator has his hands full watching those two automatic heads. The difficulty is getting out on the corner; on many of the driving wheel centers there are sand holes, and, of course, sometimes a sand hole causes the arc to break. The

operator has to be on the job all the time, and if the current is from a line where there is interference from other machinery he has to be adjusting the current. Fluctuation of voltage requires very close adjustment.

A MEMBER.—Is any cleaning operation necessary before you start welding?

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—Yes. It is not necessary to take a cut-off of the wheels, but they must be cleaned either with a wire brush or by some other method. We first started to take a cut off of the wheel but we found that we could save a little time by cleaning them with a special arrangement for that purpose in the form of a brush that serves the purpose very nicely.

A MEMBER.—You have all cast steel wheels you refer to?

MR. G. H. GJERSTEN.—All cast wheels.

A MEMBER.—Do you build up the flanges on the wheels, on your tires?

MR. GJERSTEN.—No. This is just restoring the centers to their standard size so they will take standard size tires without shimming.

A MEMBER.—Do you use all portable machines?

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—Yes.

CHAIRMAN OEHLER (*Railway Age*).—I am going to ask you gentlemen to hold further questions for a while, if you will. I don't think it has ever been my privilege to listen to anyone who has a more exact or intimate knowledge of welding in the railroad field. You have not succeeded in asking Mr. Gjersten one question that he has not answered both quantitatively and qualitatively, and I hope you will take advantage of the opportunity that you have while he is here and after the presentation of the next paper to bring out more of the points.

Mr. Gjersten has outlined the best practice of welding upon an American railroad. The next paper has to do with welding on the Canadian National. The title of the paper is "The Organization of Welding on the Railroads."* It is a long paper and the author has told me that he will rely upon your having seen it in the JOURNAL or your having copies of the JOURNAL in your hands, and will, therefore, simply outline the different parts of the paper to you and show a number of slides on the screen.

I wish also to say that you have an added opportunity in discussing this paper because the author, outside of his knowledge of welding, is also a metallurgist. I take great pleasure in presenting Mr. F. H. Williams of the Canadian National.

MR. F. H. WILLIAMS (*Canadian National Railway*).—Mr. Chairman and Gentlemen: I will just go over briefly the paper and then show the slides.

*Printed in the Oct., 1926, Journal of the A. W. S.

CHAIRMAN OEHLER.—Gentlemen, I think you have an opportunity to do a little welding engineering. If there are any of the practices that have been outlined by either of the speakers that you consider questionable, let us know about it. If there are any that you do not understand, or if there are points which may be brought out by asking questions, please ask questions. The meeting is open for the discussion of both papers.

MR. C. W. ROBERTS (*Pennsylvania Railroad*).—In the Duplex stoker job the author states the elevator will cost $99 new, and the conveyor screw the same price. Now I notice in here that he states they are reclaimed for $3—$1.50 an hour. Does this mean that all that is done is to build up the diameter of those flights so they will finish with a standard 10-in., or is there anything done to the flight to maintain the usual thickness of ½ in.? The $3 price for welding to me seems very low. In Mr. Gjersten's method of reclaiming the elevators he spoke of putting on the 2-in. by one-half bar iron, I would like to know if the elevator has to first be cut down to a certain size with the acetylene torch and then this rod applied?

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—In regard to the method that I showed on the picture of reclaiming the elevator screw—we have a limit of ⅜ in. for the allowable thickness of the screw blade. As the engine goes through the back shop; if the screw blade is down below ⅜ in. we apply the strip, which is ⅜ in. thick by 2 in. wide. We don't pay any particular attention to the thickness of the screw blade; if it is ⅛ in. over or under it does not make any difference. We don't cut off anything on the outside. Many of these screws come in worn to the extent that the outside edge is really lapped over. It has really a knife edge on it, and by applying that strip the way we do the welder pounds the screw blade and straightens it back in shape as he goes along. The outside is built up by the oxyacetylene process, and the inside is done after by the electric arc process. We have a roller gage that gages the diameter so that it is right when we are through with the building operation.

MR. C. W. ROBERTS (*Pennsylvania Railroad*).—The elevator screw will wear very uniformly, but the conveyor screw will wear very much more in the center or directly over the hopper, and I wonder what method you have of reclaiming it. Of course there are different ways of reclaiming these screws. One method is just putting on a round bit of iron ½ in. and welding with the acetylene torch or with the electric arc. Do you make any allowance for the extra wear on the conveyor?

MR. G. H. GJERSTÉN (*Northern Pucific Railway Company*).—In the conveyor screw there are three or four flights that wear more than the rest of the screw, and I say that if the thickness of the screw blade has not changed below ⅜ in., why then build it up solid. We don't put anything on it; we build it up solid. If it is below that thickness, then we apply a strip to that thicker sec-

tion and then taper it off on the ends. Possibly the strip will cover three or four flights of the screws. That is the practice we use.

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—In regard to the cost we figure—say, on an elevator screw, the average total cost, including overhead, to be about $75 to reclaim an elevator screw where they are excessively worn.

CHAIRMAN OEHLER (*Railway Age*).—Can you restate the question as applied to Mr. Williams' paper?

MR. C. W. ROBERTS (*Pennsylvania Railroad*).—Somewhere in Mr. Williams' list of "Stoker elevator electric welded" the new purchase price is $99. Then he shows the time, "reclaiming by electric welding, $3, two hours at $1.50 an hour." I was wondering whether that simply meant building up the flights of a screw to bring it back to the original.

MR. F. H. WILLIAMS (*Canadian National Railways*).—It is simply restoring. That much work was required to bring it back to standard diameter. It did not include that 2-in. strip.

MR. H. L. MORRIS.—May I ask the speaker if he has any data on building up cast iron wheels?

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—You refer to the outside diameter of the cast iron wheel?

MR. H. L. MORRIS.—Yes.

MR. G. H. GJERSTEN.—No, we have never built up the diameter of cast iron wheels. The only cast iron wheels we have left on our system is the small old type engine. As a matter of fact the cast iron wheels seem to hold their size and shape and we have never reclaimed any cast iron wheels.

MR. J. W. OWENS (*Newport News Shipbuilding & Dry Dock Company*).—I would like to ask Mr. Williams whether he uses different temperature for the annealing of gas welds and oxy-acetylene welds? In annealing, for instance, a rod that is being built up the annealing temperature for the deposited metal is different than the annealing temperature of the base metal and for that reason I have always felt that not enough work has been done to determine not only the correct annealing temperatures for both gas and oxy-acetylene welds, but also to determine the necessary temperatures for the double heating that is required for annealing these two different metals. Before I sit down I would like to bring out one other point in Mr. Gjersten's paper which I believe is well worth while—that is the failure of butt welds in the past. I believe that the failure of butt welds has been largely due to non-reinforcing, and the fact that Mr. Gjersten's practice in their shop work is to reinforce these welds from both sides, is in my opinion one of the fundamental elements in the technique of making butt welds. They should be reinforced at least from one side, and preferably from both sides. Reinforcement not only gives a larger cross section of the deposited metal, which is weaker than the base metal, but the subsequent layers that are put on, using an oxy-acetylene weld anneals all layers. Therefore you not only

get a better quality of metal in the welds, but you get a larger section than the base metal which takes care of the difference in tensile strength.

MR. F. H. WILLIAMS (*Canadian National Railways*).—Annealing of parts is, as far as I have seen, done by gas work. We haven't really got into the study of the structure or chemical analysis of the deposited metal so we could not form an idea of the proper temperature. The best practice would be to have an electrode or rod that would have a higher carbon content than the parent metal to be welded, so that the metal deposited will have approximately the same carbon content as the forging or steel that you are welding.

MR. J. W. OWENS (*Newport News Shipbuilding & Dry Dock Company*).—We would like to know definitely the temperatures.

MR. F. H. WILLIAMS (*Canadian National Railways*).—There has hardly any work been done in this field. You mention about one layer annealing another, that shows up very plainly in the microscope. You get a much finer weld than if you make it with one layer. If you make a weld of two layers you get a much stronger weld than you would with one layer, and if you fill the grooves or "V" and then put a layer on top of that you would have very nearly a perfect weld, provided you haven't any slag occlusions or similar faults. If you put a layer about the parent metal, then while that layer does not amount to anything so far as its own strength is concerned, it refines the metal in the "V" and you have better results.

MR. LUCAS.—Suppose you have a "V" weld?

MR. F. H. WILIAMS (*Canadian National Railways*).—The roads demand to do the work quickly and they put it in with one layer. They even weld ⅞ plate with one layer. They have equipment for handling that. They have got from 200 amp. machines to 300 amp. and they can handle ¾ rod. But you don't get the same strength as you do with two layers. If you added a third layer on top to anneal the one underneath you would have a still stronger weld.

MR. O. D. RICKLEY.—Mr. Chairman, in Mr. Gjersten's list of representative welds it appears that he uses gas mostly on cast iron and the electric welding on steel. I was just wondering if he found that a general practice.

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—I can say that I weld all cast iron with cast iron rod, except in a few cases where we use a little bronze, and we do a great deal of our steel welding with the oxyacetylene as well as with the arc. It depends on the job, the location, the break and the operators we have to do it with. As I said in my paper, there are many railroads and we are one of them that have not been able to supply enough welding equipment. We first, of course, had to become supplied with the oxyacetylene facilities because we had to do all our cutting with oxyacetylene and do all our welding of cast iron,

bronze, brass and so forth, and, of course, we put in the oxy-acetylene equipment as we got the appropriations.

A MEMBER.—What is your opinion of welding locomotive parts with bronze?

MR. G. H. GJERSTEN.—In the first place I have a little respect for the looks of a job. If I want to have a patch put on my trousers I don't want to have a piece of canvas put on them, even though it might be just as good. The same with machinery, and while bronze might be just as good, the looks of it also have something to do with it. I think if it is steel it should be welded with steel, and if it is cast iron it should be welded with cast iron. Put the same material on that you take out and have a 100 per cent job.

CHAIRMAN OEHLER.—The paper that has been handed here will be included in the discussion.

Static Tensile Test of Two Pieces of Stay Bolt Iron Butt Welded in Center, for Grand Trunk Railway System

November 4, 1926.

Length between punchmarks before test	2.47 in.
Length between punchmarks after test	3.32 in.
Stretch	1.35
Per cent elongation	54.65 per cent
Ultimate load	31,000 lb.
Breaking point	27,300 lb.
Location of fracture—in shank, not at weld.	
Cracked at weld.	
Registered tensile on ⅞ in. diameter test piece	30,000 lb.
Actual	31,000 lb.
Registered tensile	47,000-52,000 lb.
Test piece	.875 in. diameter
Registered per cent elongation	30 per cent diameter

MR. F. H. WILLIAMS (*Canadian National Railways.*)—In one of our shops we tried the welding of bells with the arc by reversing the polarity of the D.C. We welded a 5-in. vertical crack and it cost about $1.75 for cutting out and finishing up, and we found that the tone of the bell had not changed, and the job was perfect. I thought it may be just as well to mention that you can use the electric arc on the welding of bells as well as gas torch.

A MEMBER.—What metal did you use in reclaiming the bell?

MR. F. H. WILLIAMS (*Canadian National Railways*).—The metal we used was the special bronze silicon plastic iron. You had to do the work very quickly. The rod feeds in very fast, but when the job is done the tone is not affected, because the heat is concentrated in one place and it does not distort the bell at all. This bell was not preheated; it was welded cold.

MR. F. A. RYAN.—When welding a crack or fracture some times you use the single "V" weld, and at others you use the double "V" weld, or weld on both sides. Does not that depend on the thickness of the metal?

MR. G. H. GJERSTEN (*Northern Pacific Railway Company*).—That would depend, as I see it, entirely on the job. When jobs may be 2 in. thick or 3 in. thick it may be advisable to weld them

from both sides. But it is not always possible—most castings are constructed so that you can only get at them from one side. If you were welding plates it would be different. The heaviest we have, of course, is boiler plates, and what we are welding in boilers is all done from one side, up to 7/8 in. and possibly 1 in. We always touch it up on the opposite side. But if I were to weld a section of a frame or anything of that kind thicker than 1 in. I think it would be to advantage to weld it from both sides—if you can get at it from each side.

MR. OWENS.—In material up to say 3/4 in., if it is reinforced from both sides it does not make any difference in strength whether that weld is V'd from one or both sides, you can get a 100 per cent strength.

Meeting adjourned to 2 p. m.

AFTERNOON SESSION
November 17

Discussion: Structural Steel Session

MR. J. H. EDWARDS, Chairman.

The chairman called the meeting to order.

(Paper on "Comparative Tests on Arc and Riveted Structural Members," by A. M. Candy, General Engineer, Westinghouse Electric and Manufacturing Company.)

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—I am sure Mr. Candy will be glad to have you ask any question or discuss any features of this paper.

A MEMBER.—Mr. Candy, have you any idea of the comparative cost of welding such buildings as compared with riveting the building?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—I would rather have Mr. Edwards answer that question.

A MEMBER.—Has anything been done in the way of car welding —steel car construction?

MR. A. M. CANDY.—You mean railway freight cars?

A MEMBER.—Yes.

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—There has been a few cars spot welded. I am not sure whether there has been any arc welded. I can say this, however, that the government railways down at Sidney, Australia, have welded trucks and the plate frames for several gasoline electric cars on government railways, and the last report I got from them, trucks which had been in the service for a period to exceed five years, have never caused any trouble whatsoever.

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—I think it would be of more interest to all of us if the people who discuss the paper will rise and give their names.

MR. BOURKE.—In using a ¼-in. rod the speed of welding is faster than for smaller diameters. Is the tensile strength any less? The appearance on the outside of the work did not look as smooth as the 3/16-in. rod.

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—That is getting us into territory that is quite debatable. Personally those of us connected with our company and who have investigated welding from every angle that we possibly could are pretty well convinced that we get better results by staying down to a lower size of welding wire and using lower currents than if we used larger wire. We have gone up as high as ⅜ and ½ in. and a current that would give the good fusion with that wire and at least from a technical standpoint, we don't get as good results as if we keep down to a 3/16 wire. The resulting weld with a larger rod hasn't good ductility nor as much tensile strength.

PROF. C. H. ADAMS (*Harvard Engineering School*).—Is there any caution necessary to get the length of the beams and parts and plates more exact than they are in riveted structures?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—I would much prefer if you would address that question to the chair, Professor Adams. In fabricating these members which have to go into these buildings, they have been held down to a very much closer allowance than they are for present riveted construction. However, after seeing this steel go together at Sharon I am personally, at least, beginning to wonder whether it is necessary to go to the high degree of refinement that we have done on this first structure. This is the first job to amount to anything with us at least and we want to be dead sure that we would have a structure that would go together and give the welders the least possible annoyance. We wanted everything to fit as accurately as possible. I doubt whether future work is going to be done with that high degree of accuracy. Personally I believe that we are going to be able to make our joints and design a structure so that we can give greater tolerances and still have just as good a job as we have now.

MR. E. F. BARRY.—There was one point the speaker did not bring out and that is longitudinal shear. Did you have any trouble between the cover plate and the web? There is only a small area carrying that shear.

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—No, there was absolutely none in the specimens which I showed, but a similar type of girder more closely approaching these larger girders that we have in our buildings was made up under Mr. Edwards' direction and tested at the Bureau of Standards.

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—I think we will hear about that a little later. Are there any other questions?

MR. STUBB.—I wondered whether the question of tack welding on each end as material is erected has been looked into, thereby saving all punching and handling in the shop for these bolted connections for field erection.

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—I think if the man that asked that question would have seen the speed at which that building was going up he would have found out very quickly that that would be impossible. They made those connections so quickly that you could not have a man around there to tack it.

MR. J. C. BENNETT (*Associated Oil Company*).—In the design of these connections is value given to the added strength of beam due to the erection angles, the landing angles? Are they included in the strength of the joint?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—I don't think there is any question but what some strength should be given to these fittings.

MR. J. C. BENNETT (*Associated Oil Company*).—I would like to know whether in the actual structure you include in your final strength of joint the added metal which you do gain by reason of your landing angle—your shelf angle?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—Oh, yes, absolutely. The designing engineer that laid out the structure figures his stresses at the joints and we are arbitrarily using a value of 2500 lb. per lineal inch on a 5-ft. 6-in. beam. Then he puts on his set angle and reinforcing plate and he figures all that metal that goes along that plate and on the end to get enough to carry that stress on that basis.

A MEMBER.—I would like to ask Mr. Candy if a man working on the top story finds any loss of heat in the work as compared to the bottom or the first floor?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—There is nothing lost by this distance. I don't see why there should be. You have got so much more steel to carry the current than the welding cable, so there is not much difference.

A MEMBER.—The reason I asked the question is that some of our operators after they are operating on a wire are losing power.

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—If you double the same length of cable you are going to have twice the drop in current. If you use the same size of cable to run 300 ft. away then you are going to have a greater amount of voltage loss to get that current through that cable to the operator than for 100 ft. It would be quite a long trip from the eighth floor of a building to the ground to adjust a machine. You get the current set right once and it is good for several hours. Take one of those typical joints; there is as high as six or eight hours' work for one man. He does not have to go down every five minutes to change the machine, and even if he should need a

change you have got to have a welding supervisor on the job to keep track of things to see that the welding current is all right. Details like that hardly enter into the major problems because those things are so easily overcome and don't make a whole lot of difference.

MR. H. W. CONDON (*Providence*).—If there was some bad welding what would be the procedure to get that metal out and put other metal in?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company.*)—We have got an inspector. He looks at the welding. If it does not look like a good weld he whistles for George and has him chip out the weld and see if it is a good weld.

MR. THOMPSON.—The whole criterion of that is the looks of it, the same as a riveted job?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company.*)—Yes, especially when the supervisor looks over the operator's shoulders. It is not difficult at all, and I think Mr. Edwards can back me up when I say that we can predict whether a weld is going to show up satisfactory.

MR. CONDON.—There is one other question—you spoke of corrosion and getting rid of some of that corrosion. On one job I noticed some of these bare joints. After welding was there any tendency for the paint to disappear? Is there any action, any oxide left there that tends to make the paint come off?

MR. A. M. CANDY.—That I don't know. This is possibly getting beyond my depth. I will say this, that all the steel that is going up on the Sharon Building is being painted. I looked over some of the painting. The paint over the welds showed up as good as any. In ship work, probably Mr. Owens can give you as good testimony as any one. They have been welding on naval vessels in the navy shipyards for a number of years. Mr. Owens had charge of all the welding at Newport News. I wonder if we can get some light on it from Mr. Owens.

MR. J. W. OWENS (*Newport News Shipbuilding & Dry Dock Company*).—Mr. Candy, in reply to that question, I would say I haven't noticed any difference in the appearance of the weld in sea water.

MR. MARLBORO.—Has there been any notice taken of the work done by a welder on a very windy day as compared when there is no wind?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—That will give you a chance of going into some minor interesting stuff if I wanted to go into it, but I am going to keep my feet on the ground. The day I was up it was a pretty windy day and I started across the 12-in. "I"—the wind hit me—I returned to the landing. The welders had absolutely no difficulty using bare wire over on those jobs, even with the worst winds we had, damp, around 20 and below, and snow and wind all at the same time. In fact, some of them prefer the bare wire to the coated wire.

MR. CHAIN.—Do you have to remove shop paint from the structural section before you start to weld?

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—We don't paint them at all. We coat the metal with linseed oil. So far as I know we are having no trouble.

MR. F. H. WILLIAMS (*Canadian National Railways*).—With regard to the question of paint peeling off, there was one bed manufacturer who used acetylene welding. They found that after they had sent the beds out, in about six months they started to peel at the weld and on investigating they came to the conclusion that the flux formed a scale over the weld so that the paint did not reach the metal, and when the first moisture dissolved that flux the paint fell off. So if the weld is clean, without any flux coating, it is very likely that the paint would remain there. If there is something between the metal and the coat of paint it will peel.

I would like to ask Mr. Candy if the deposited metal is of a similar chemical content to the steel, or higher or lower carbon.

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—The welding wire has about the same analysis as the steel, but after going through the arc will naturally give you less carbon in the weld than the steel in the structure.

A MEMBER.—Were any special pains taken to clean the joints, especially the work that was done in the field?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—Questions like this are very difficult to answer because it is a question of relative amount of rust or relative amount of paint or relative amount of linseed oil. Take all our test specimens—that we welded at East Pittsburgh and tested at Carnegie Tech—they came back with a little rust on them. We cleaned them off with a wire brush. The welders have some chipping hammers, so when they get to a joint where the scale is too thick they chip it off until they get down to a fairly decent surface. However, I don't think it is going to be necessary to have every joint ground to have excellent virgin steel.

SAME MEMBER.—If you have a certain clearance between the end of the beams and the web that it connects to, and if you had a very heavy web, say a three-quarters or five-eighths web, would it be necessary to bevel the web to make a good joint? Assume that there is a quarter of an inch clearance between the end of the beam and the web that it connects to. I understand with a good butt weld you have to bevel the edges.

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company.*—No. Take large members in that building, 20-in. "I's," none of those have webs anywhere near three-quarters of an inch thick. The structural steel designer figures out what stress he has got to withstand. The designer shows on his drawing enough inches to give him enough metal to base with that 2,500 pound value to bear that stress. We may have more inches around that material. We don't make an attempt to get a weld completely

around. There may be a 3/16 in. gap—we do not penetrate back there over one-eighth inch, probably not more than 1/16 in.

MR. R. E. WAGNER (*General Electric Company*).—I would like to ask Mr. Candy if he is using any electrodes larger than 3/16 in. in diameter and if he is putting the weld metal on in more than one layer?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—The largest wire we are using either in the field or on the job is 3/16 and on some jobs we are using 5/32. With the size of wires that are being used in this particular job where a large amount of metal is required, we put in several layers. Take the web plates that are welded in on the bottom flange of a beam girder on which another beam is fastened, there is quite a gap in there; it will take some eight or ten layers of weld metal. We are not attempting to make all the weld in one pass and fill it up as we go along. We believe, and it is well substantiated, that it is better to put in a number of layers, each layer thoroughly brushed off with a wire brush.

MR. MARLBORO.—I would like to ask Mr. Candy if the experiment of this building is successful which will you tackle first, the domestic building or the commercial building?

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—I think it is a long, long ways before we can answer that question. My vision is not quite long enough to foresee.

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—We want to sell welding material and apparatus, and we want people to first know how to weld, and then get organized in business to build everything by welding.

A MEMBER.—I assume the current you use is in the neighborhood of 250 or 300 amperes.

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—We are not using that on 3/16 wire. That is too high for 3/16 wire.

A MEMBER.—What current did you use?

MR. A. M. CANDY (*Westinghouse Electric & Manufacturing Company*).—We are using between 200 and 225 amperes on 3/16 wire.

CHAIRMAN EDWARDS.—The next paper is "Tests on Welded Roof Trusses,"* by H. H. Moss of the Linde Air Products Company.

MR. MOSS.—Mr. Candy's very interesting paper and these discussions leave with us a great deal of food for thought, and I know when they get through with that job in Sharon they will be able to answer a lot of questions quite satisfactorily. A great many of them are controversial, and the actual field experience designates the answer, and I know they will be forthcoming when they get through with that job.

*Published in the Oct., 1926, issue, Journal A. W. S.

The substance of the paper which I am prepared to read before you this afternoon revolves around the experimental work recently conducted by the developmental section of the engineering department of the Linde Products Company, looking toward a practical method of oxyacetylene welding light steel structures, the development of steel roof trusses being one phase of this project that has reached the practical stage study.

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—You have the paper before you for discussion and I would like to repeat what I said before, will you please confine your questions and remarks to the paper. If we have any time we will have an open discussion later.

MR. BONTON (*General Electric, Springfield*).—Mr. Moss's paper is of so much wider interest than only from the standpoint of welding that I would suggest that all his data be submitted to the American Society of Civil Engineers for publication in their proceedings. The paper includes much data of great interest to engineers at large, and I am sure that the structural section of the American Society of Civil Engineers would be very much interested in it. I want to commend Mr. Moss on the excellent way in which he approached this problem and the fearless way in which he showed his test results.

PROF. C. A. ADAMS (*Harvard Engineering School*).—My interest in this whole problem from the beginning of the organization of the Society was to bring welding more into the scientific realm, to place welding on a really sound scientific basis, and this is just exactly the kind of work that has got to be done by the welding fraternity. Careful, thorough, fundamental investigation of the subject so that we know exactly where we are at. All these stress measurements were probably more thorough than most of the work that has been done in connection with riveted structures. They have sufficient structures which have proved themselves satisfactory in the long years of experience. But we have got to show the non-believers what we can do, and we cannot do it unless we do it in this same thorough fashion, and I wish to express the highest possible appreciation of this particular job.

MR. MOSS.—I overlooked stating the fact that Mr. Edwards had an interest in this work and took part in it.

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—I wish to bring out one point that occurred to me as a structural engineer that may account possibly for the difference in strength in the trusses. It is a matter of application of welding which we can apply possibly even in a compound structure which will give us greater strength. Take a section of the top part of the trusses (drawing diagram on blackboard). The strength of the compression member depends upon holding all its members in line. If one compression member gets out of line, there is a tendency of the whole to buckle. The top chord is fastened with a washer and a

rivet. Under compression we find the compression taken by a single or double angle which tends to go this way or that way, and when it gets a certain distance your whole member goes sideways as you saw in the illustration.

In the welded structure you have a somewhat different condition. The angles, while they work separately, are like two drunken men going down the street; one helps the other sometimes. (Illustrating on blackboard). If one angle attempts to go this way, the other one, perhaps, stiffens a little and helps the other to some extent when they are close together. It was not brought out in the sketches which you saw that the joints of the riveted trusses have this detail with washer and rivet. The welded truss was welded there. I think it is very evident what effect that welding had on the strength of the compression member between the panel point.

PROF. C. A. ADAMS (*Harvard Engineering School*).—Is that something like the difference between two boards of half the thickness of a single one? That is, the whole structure is more rigid and they help each other out; whereas if in the other case, the more independent and weakest one buckles first, without the assistance from the other?

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—That is the idea, and at the same time in the welded truss you are holding the outer edges of your members which prevented a secondary buckle before the primary failure took place.

MR. W. SPRARAGEN (*Secretary A. B. W.*).—I would like to hear Professor Whittemore, if he is here, describe a test he made at the Bureau of Standards on a welded girder.

(Mr. Herbert L. Whittemore, Chief Engineering Mechanics' Section, Bureau of Standards, Washington, D. C., gives a talk, illustrated by lantern slides, on a test made on a welded girder.)

Editor's Note.—This will be printed in an early issue of the JOURNAL OF THE A. W. S.

MR. SPRARAGEN (*Secretary A. B. W.*).—Mr. Chairman, while this room is dark I would like to show some slides I had made up in connection with a paper I presented before the American Institute of Construction on the subject of welding structural steel. I picked out a few slides of some structures that have been built in other countries besides our own.

(Mr. Spraragen gives a talk, illustrated by lantern slides on welded steel structures.)

Editor's Note.—Copies of this paper may be obtained by application to the secretary of the American Welding Society.

CHAIRMAN J. H. EDWARDS (*American Bridge Company*).—I think we have a little more time if anybody wants to ask any further questions.

PROF. C. A. ADAMS (*Harvard Engineering School*).—Mr. Chairman, I wonder if Mr. Moss can give us any notion as to the relative cost of these trusses as compared with riveted trusses?

MR. MOSS.—Professor Adams, in reply to that question, would say that I feel that we are not in a position as yet to advance any definite or reliable information in regard to cost. We have kept the records of our material and labor at Buffalo, and while they indicate economy compared to riveted construction, how much that will be we cannot say. It appears, we will save, between 25 and 30 per cent of the amount of material, and that represents a sum of money which would offset the cost of the layout and fabrication, and I daresay if we had a number of trusses to erect of that type, where a crew would become skilled, the method would make for economy. When we get a little further along we will have some information to add on cost because we are vitally interested in that ourselves.

MORNING SESSION

November 18

Discussion: Welding Science in the Engineering Curriculum of Universities

PRESIDENT F. M. FARMER.—The meeting will please come to order. The subject of this session is the broad one dealing with the teaching of welding in universities and technical schools. This is a new subject for this society to be discussing, but some of us feel that it is one of the most important activities which the society can promote.

The welding society is organized primarily for the purpose of promoting the interests of welding.

We all appreciate that one of the handicaps under which the process has labored since its inception has been the lack of a sufficient number of technically trained minds directing the application of the art in industry. We need more trained technical engineners who can take hold of this process and apply it with a maximum of intelligence and with maximum efficiency and results.

The engineer who has specialized in the welding field is not going to be grown over night as he has got to be developed. Obviously the place to begin development is in the incubator. We therefore feel that this is a most profitable field of activity for the welding society to be engaged in. While the result of these efforts will not be immediate, like some of the other activities that we are engaged in or hope to be engaged in, we believe that in the future we will reap the benefits many fold.

Therefore, we inaugurate this first session on this subject with a great deal of hope, and I think the Meetings and Papers Committee feel very much pleased with themselves at the success with which they rounded up enough men on the teaching staffs of our colleges to take the trouble to prepare papers on this subject and come here and present them. We found a rather unusually prompt response to our suggestion.

Now, as is customary in conducting our meeting, the president turns the chair over to various of our officers and prominent members and on this occasion there will be no exception.

I am going to ask Professor Adams to preside at this session.

PROF. C. A. ADAMS (*Harvard Engineering School*).—I suppose, gentlemen, I am put here to make the other professors feel at home. I don't think I can add very much to what the president has said in regard to the need for welding engineers. This industry differs from—well, for example, the electrical industry. The electrical industry grew up out of the science which had been pretty thoroughly developed before the industry took hold at all. The welding industry grew up out of little shops here and there in the hands of practical men. The question as to whether they succeeded or not was largely a temperamental matter. They often failed when it came to anything that required quality, and even today very large undertakings fail merely because of lack of what some of our men have called procedure control. In other words, the engineering end of the job has not been thoroughly worked out. When I say they fail today, I have in mind a particular instance of a very large and important project about which, perhaps, some of you know. Now that kind of thing is what gives the industry a "black eye," as we say, in the minds of the standpatters, the conservative men. And you can't blame them entirely. They are, in many cases, in responsible positions and they have to be shown. They are not digging into the thing and finding out all the facts and the reasons for these things. They simply say, "Why, here, you failed. This weld has failed," or "this job has failed." And, as I say, the reason for the failure in nearly every instance is the fact that there has not been on the job a really competent welding engineer.

All the men that have a right to claim that title ought to have grown up with the industry. But you need something more than the practical man's accumulative knowledge. We need a man who is trained in the fundamentals of science, who, when he observes something and thinks it out, says, "Yes, that is because so and so." And if he cannot quite think it out he makes a series of experiments and digs in until he finds out the reason why and the relationship.

Now, most of that work in the welding field has been done so far by our corporations, our men connected with them and your society in a cooperative way. These corporations have laboratories where the work is going on, but there are not as yet a sufficient number of men really competent in this field. Hence, as the president has said, this subject is one of vital importance to the society, and there is every reason why we should make some organized attack on the educational institutions of the country.

Frankly it is a very pleasant surprise to me to find as many professors of engineering as we have on this list who are sufficiently interested and informed on the subject to discuss it.

CHAIRMAN ADAMS.—Professor Hart of Syracuse University.

(Paper on "Welding Science in the Engineering Curriculum of Universities"* by Prof. S. T. Hart, Mechanical Engineering Department, Syracuse University.)

CHAIRMAN C. A. ADAMS (*Harvard Engineering School*).—If I had been asked to discuss the subject I would not do any more, I assure you, than hammer away at the thing that Professor Hart has talked about here, namely, the fundamentals, providing a foundation on which the men can build.

Just stop to think for a minute what our engineering schools have got to do. As each new development comes along we have to tell them something about it, and the curriculum is being crowded and crowded and crowded all the time. It is absolutely impossible to train men in the technique of the engineering profession as broadly as they should be trained. All you can do is to give them a foundation on which to work. A man who has a sound knowledge of metallurgy, chemistry and physics can acquire all the knowledge of welding he needs in a comparatively short time. If his knowledge of welding is to be purely empirical, merely a collection of facts, it would take a large amount of time and a very good memory for him to make any successful use of it. But if his practical contact with the subject, his knowledge of the facts from observation of them suggests always a reason why, he is constantly thinking and trying to explain what he sees and what he learns and it fits into a scheme of things—if you will, the theoretical scheme, as far as we can get it, of our knowledge of the structure of material. Then it is systematic knowledge and grows and grows consistently. If he finds a now problem, he does not try to get along with the superficial phase on the outside, he starts from the bottom and builds up.

Now that is what the engineering schools ought to be trying to do. Apparently Professor Hart is trying to do it.

I am also astounded to find out the amount of training that his men get in this particular field. I think it is fine. In my own institution all the men get on welding is a couple of lectures from me every year, the general lecture that he outlined here at the end of his talk.

The next paper is by Professor O. D. Rickly of Ohio State University.

PROF. O. D. RICKLY.—First I want to thank the American Welding Society for extending the invitation to our university to participate in this discussion. By doing so, of course, we learn from men who are out in the field, from practical men, and it is the linking of the practical side with the theoretical side that makes the thing go.

(Paper on "Welding Science in the Engineering Curriculum of

*Published in the Oct., 1926, JOURNAL OF THE A. W. S.

Universities"* by Prof. O. D. Rickly, Ohio State University, Columbus.)

CHAIRMAN C. A. ADAMS (*Harvard Engineering School*).—I am sure we appreciate this very concise paper by Professor Rickly and I think he has the right idea as regards instruction.

The next paper is by Professor Larkin of Lehigh University.

PROF. F. V. LARKIN.—Gentlemen, I am coming here this morning in a very humble attitude. We realized some time ago that the progress being made in welding was ahead of the progress that we were making in giving instructions in welding. That was brought to our attention very forcibly a couple of years ago by a meeting which was held by the American Society for steel treating in which they devoted an afternoon and evening to welding work. The meeting was held at the Exposition Building of the Bethlehem Steel Company, and a great many exhibitors were there and a good many papers were given. It happened that afternoon I was able to take the Junior and Senior Mechanical Engineering students down there, in lieu of a laboratory period. I found that the boys had a genuine interest in the thing, a good deal of curiosity and we decided then and there that it was high time that we were doing something in the matter of general instruction in welding. We therefore arranged to get welding equipment on the job and plan some means of getting it before all of the students. (Paper by Professor Larkin published in this issue of the JOURNAL.)

CHAIRMAN C. A. ADAMS (*Harvard Engineering School*).—I am getting rather proud of the teaching profession. You are hearing a little bit about the problems of the engineering teacher. Professor Larkin has brought out some of these problems. I wish that this society could have a meeting each year on these same subjects, the subject of welding engineering education. Engineering education is not so far different—whatever a man wants to follow, the fundamentals are the same if he knows how to apply them.

I am going to ask if Professor Turner has come in since the meeting opened? Professor Turner of Purdue had one of the papers. Has Professor Lucas come in? If not, I will ask Mr. Swain, chairman of our Meeting and Papers Committee to read these two papers. They are not long. Then we can open the discussion.

MR. P. W. SWAIN (*Assistant Editor of Power*).—The first paper is by Prof. W. P. Turner, Professor of Practical Mechanics, Purdue University. The title is "Welding Science in the Curriculum of Engineering Universities."

I will read the next paper, which is very short. This is by Ernest L. Lucas, Associate Professor of Mechanical Engineering at the Mississippi Agricultural and Mechanical College. The title is "Welding Science in the Curriculum of the Mississippi Agricultural and Mechanical College."

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*Paper published in the Oct., 1926, issue, JOURNAL A. W. S.

CHAIRMAN C. A. ADAMS (*Harvard Engineering School*).—Gentlemen, I think you agree that these papers have given us not only a perspective of the problems from different points of view, but they must suggest to your minds methods by which we may all perhaps help in this important job of welding engineering education.

The thing that occurs to me, that stands out most prominently, is the part which the society must play in helping the engineering schools and colleges of the country to do this job in the best possible way. That is what I had in mind in suggesting an annual session on this subject. The fall meeting, being accompanied by an exhibition, is usually much more attractive than the annual meeting in New York and we have a much larger attendance, and that I think would be the place for it. It is entirely possible that an education committee of the society might be organized which would do two things. It would help the educational institutions in their job, and it would help the society in broadening its contacts and making it better known amongst the younger men of the country who are coming up in this profession.

These papers are now open for your discussion and I am sure you will have something to say on the subject.

MR. J. W. OWENS (*Newport News Shipbuilding & Dry Dock Company*).—Mr. Chairman, I have prepared a short discussion on the subject, which I will read.

Gentlemen, when the society was first organized, I think it was in 1919, as a continuation of the Committee of the Emergency Fleet Corporation, I remember well when the question of the name of the society was being discussed. The name suggested at that time was the Society of Welding Engineers, and I remember the comment that we could not call it Society of Welding Engineers, because there were no welding engineers. I believe if the society were organized today that instead of being called the American Welding Society, it would be called the Society of Welding Engineers. That shows the growth of the industry and how it has changed in its aspect and breadth and what a difference in view we have of the engineering as a science today.

The presentation of a symposium on "Welding Science in the Engineering Curriculum of Universities" by faculty members of five universities, is not only timely but a master stroke of the Society's Meetings and Papers Committee.

As the subject is one to which I have given considerable thought, I am convinced that in the training of our young engineers in the fundamental principles of welding lies our hope for a sound and rapid advancement of the science. My efforts along this line have been instrumental in interesting at least two technical colleges in the subject, in one of which an excellent thesis on "Properties of the Non-rigid Type of Arc Welded Joint" was submitted by a post graduate student in 1925.

Excellent service has and is being rendered by manufacturing concerns in the development of welding; however, in practically all cases the interest of the individual concern centers around the utilization of some one form of welding, whether it is smith, electric, resistance, gas, arc or thermit. The university, on the other hand, desiring to teach welding as a science, must of necessity see to it that each form of welding is giving proper consideration, as any one form is only a part of the whole subject when considered as a science. The extensiveness and thoroughness of the course given will have to be governed by the many factors which determine any engineering course in a university. In no case, however, should an attempt be made to graduate students who are expert mechanics in either form of welding but rather engineers grounded in the fundamentals of welding science, the training of mechanics being properly left to the trade school. In view of the foregoing, I would suggest the following brief outline of the course I have in mind:

Lecture Course

Lecture 1 Brief consideration of each form of welding with a view of acquainting the student with the extensiveness of the subject and the inter-relation of each form to the other. The welding chart distributed explains my ideas along this line and should be of assistance to universities planning a course in welding.

Lecture 2 Nomenclature.
3 Preparation and Finish.
4 Gas Welding.
5 Arc Welding.
6 Resistance Welding.
7 Thermit Welding.
8 Gas and Arc Cutting.
9 Metallography of the Weld.
10 Residual Stresses.
11 The Speed and Cost of Welding and Cutting.
12 Choice of Metals.
13 Design.
14 Inspection and Tests.
15 Production and Distribution of Oxygen, Hydrogen and Acetylene.
16 Arc Welding Generators and Transformers.
17 Welding and Cutting Machines.
18 Welding Rod, Electrodes and Fluxes.
19 Protectors and Safety Precautions.
20 Shop and School Layouts.
21 Training of Practical Welders and Supervisors.
22 Standard Specifications.
23 Fractional Applications.

Practical Course

Practical instruction in the mechanical technique of each form of welding in a properly equipped laboratory.

While the usual university course taken by engineering students during the first two or more years is general and equally applicable to a student specializing in welding, nevertheless the general courses in electrical, mechanical, civil, metallurgical and chemical engineering are highly essential for a complete knowledge of welding both academically and professionally; therefore, the specialized welding course should be interwoven with these. As welding applications are as broad as industry itself, a condensed course in welding should also be included in the university curriculum of the major branches of engineering, so that every engineering graduate will have some fundamental knowledge of the subject to fit him, in case he is called upon, to design and supervise welded pressure vessels, steel buildings, bridges, ships, etc., and the time is not far distant when such men will be in demand.

CHAIRMAN C. A. ADAMS (*Harvard Engineering School*).—I am sure we all appreciate this carefully thought out discussion of this subject and it forms a starting point at least for the work that I suggested for the appointment of an educational committee. Mr. Owen spoke of nomenclature. You will find that he has in this paper a fairly comprehensive scheme of the whole welding field and has given names, most of which are accepted in commerce, but there is no authority at the present time as to the use of some of these names. They are natural evolutions, but it occurs to me that it might be a very valuable piece of work for the Society to undertake.

He has spoken of the alphabet in language, the use of words. Most of the differences between people in discussion, I find arise from the fact that they don't talk the same language. They are not careful to define exactly what they mean by the words they employ, and they really don't understand each other.

Our whole interest in this subject is to get guesswork, looseness and superficiality out of the field, and in every other branch of engineering we have in every one of the societies, groups involved in standardization, nomenclature, definition and even symbols that are the basis of standards. You have got to define words before you can use them intelligently. There is an enormous amount of work being done in these other fields of engineering in that particular respect. And that is one of the jobs which this society could well undertake. We have already undertaken jobs which are essentially standardization—standard tests for welds and things of that sort. But these have been little jobs that have been of immediate interest and not broadly comprehensive. So that another one of the tasks that the society ought to undertake is that broad problem of standardization.

MR. P. M. SWAIN (*Assistant Editor of "Power"*).—I am par-

ticularly interested in this subject for two reasons: first, because of my interest in the welding field and secondly, because for two years I was an instructor in engineering and I have followed with some degree of interest the investigation of engineering education now being conducted by the society. All men who have studied engineering education, and the speakers today included, have pointed out that you cannot expect the schools to do more than give a general training. If the welding industry went to engineering schools and asked them to put welding into the curriculum on the basis of teaching them some specialty, it would doubtlessly be thrown out; it would not be accepted. They are making this proposal on a different basis.

There are three ways in which the engineering schools can teach welding: they can put it in their shop work. That apparently is what has been done mostly so far—not with the intention of making skilled practical welders, but giving the man a certain degree of familiarity with the apparatus, which he can develop further if the occasion demands. The second is in the design course. I think that is one of the most important things yet to be done; the teaching of welding design along with design of riveted joints, as soon as data is available by which you can make reasonable calculations. I believe that is a very important point, so that when an engineer goes out of college he is as familiar with a welded joint as with a riveted joint. The welding industry should not urge the use of welding, but merely to give the student as much knowledge of welding as possible.

In any practical field it is pretty well demonstrated that an amount of solid fundamental research will pay the very best dividends.

CHAIRMAN ADAMS (*Harvard Engineering School*).—Mr. Swain's reference to fundamental research perhaps may recall to the mind of a few of you who heard my talk to the society before, that it is one of my hobbies, but we have got to that point where it is no longer necessary to argue about it. Every one of our big manufacturing concerns that have real research laboratories tell the same story, the actual return, financial return from these laboratories is approximately ten times the annual cost. That perhaps is not a thing which you can, say over a one year period, but over a long period—that often one discovery in a research laboratory will pay the cost of running that laboratory for ten or twenty years.

Now it is obvious that when that happens it may mean either a great improvement in a product or a great reduction in the cost of the product. If the latter, it means in the long run, competition. It does not mean that that company is going on to reap that financial reward indefinitely, because somebody else is going to do something if they are on their toes, and it is a constant striving to do the thing in the best possible way to get the best possible results.

A responsible representative of the telephone interests stated on one occasion when I was present that they were spending approximately twelve million dollars a year in research. Now if any of you are familiar with the Bell Telephone laboratories, you know that much of their research is what would appear to the uninitiated as having no connection whatsoever with the practical side of the job. The same is true with the research laboratory of the General Electric Company where they employ, not engineers, but physicists and chemists of the highest possible type. The Bell Telephone representative also said that the result of the research work was a saving of approximately sixty million dollars. It does not mean that they are going to go on getting that, but if they keep going, keep ahead of the game, something else will come along so that it will mean in the long run that much saving to them, and what is more a saving to the nation as a whole. It is a broad gaged view which they have to take. The welding industry is coming around to that same point of view where they realize that it is not only something for the immediate future, something to save them money this year, and the next year, but also that it is a public job and one of national importance.

MR. W. W. PETRY (*Middletown, Ohio*).—In different universities where there is being taught welding and other mechanical means, I believe, if the degree of W. E. were to be conferred on any graduate student, it should be the hardest degree in the university to obtain. For instance he should have a good fundamental education in electrical engineering, in chemical engineering and mechanical engineering, and of course metallurgical engineering, because he has problems such as these. Who in a mechanical engineering college can not find out the electrical potential between one plate of a smokestack and the next plate adjacent to it? That is a little problem that has confronted mechanical engineers for some time, namely, that a riveted joint in a smokestack is always subject to a great amount of rapid deterioration through rusting. The real cause of that is that there is a difference in potential between the adjacent plates causing a liberation of oxygen from the air, which oxygen increases to a very marked degree the rusting deterioration of the plates. Little problems along that line are always confronting him. Men specializing in welding engineering should have a good fundamental education. I think it would be a mighty fine step for the university to arrange a course to specialize in welding, to turn out leaders in welding.

MR. G. A. CALDWELL (*Mississippi Valley Structural Steel Co.*).—I arranged some tests on some welded trusses in our home town and invited the architects of the city to be present to witness the tests. The most of them responded, but one man of middle age and of a high standing in the profession sent word that he was not interested in welds and did not care to witness any tests. That attitude of some people is hard to overcome, and I realize

that the architects and engineers and universities have a big responsibility in taking up and being sponsor for a new industry that has not been demonstrated. It seemed to me that the universities' function in this subject of welding would be to create in their students a fair attitude or a receptive mind on the proposition of welding. That is about as far as we would be justified in going at the present stage. There is no doubt that this new method of joining structures presents a great opportunity for immense savings, and at the same time it offers a possibility of some great disaster. So the attitude of architects and engineers and universities is rational. The possibility of disaster and savings or advancement of a great industry must be balanced one against the other.

CHAIRMAN C. A. ADAMS (*Harvard Engineering School*).—I want to say that the attitude of mind referred to by the last speaker that he desired to give to the students of our universities is the attitude which every educated man is supposed to have. That is one of the functions of education.

PROF. P. GILLESPIE (*University of Toronto*).—As a visitor from Canada, I would like to express my appreciation of the opportunities of gathering this information here today, and also my agreement with the position taken by Professor Hart, indorsed by you and indorsed by subsequent speakers—that is, the danger of overspecializing the instruction of engineering in some of our schools. I was speaking to the chief engineer of one of our Canadian bridge companies and whose organization absorbs a few of our graduates every year, and speaking on this particular subject he said, "I don't care a gill of beans whether these students know much about shop practice or practice in the drafting room. As long as they are pretty well instructed on mechanics and mathematics, we will do the rest in our organization."

President Butler emphasizes the same fact. He said, "It is educationally unwise to professionalize the courses of study in a college, for two reasons: we haven't time to do it, and, secondly, the practice of the art changes while you are in the act of teaching."

On the importance of the welding industry there can be no difference of opinion, but as to methods of welding there may be an honest difference of opinion. I think that there is a service that the technical college can render to such an organization as this. Where they maintain a research organization, and do a certain amount of post graduate work, I think that through a thorough cooperation of such an organization as yours from whom they will receive direction and advice they can perform a real educational service. The men that undertake this research work are not hampered by a great body of other subjects that they have to devote their attention to. They have access to a respectable library, they have a certain amount of advice, they are pretty well instructed, let us assume, on such a basis as structural en-

gineering, physics and chemistry, which are essential for a man if he is going to undertake some of the specialized problems that some of your committees have suggested.

CHAIRMAN ADAMS (*Harvard Engineering School*).—I wish to express the highest appreciation for what Professor Gillespie said, because he has voiced exactly my sentiments. If a man is grounded in metallurgy, chemistry and fundamental engineering, it doesn't take very long to acquire the special application of those things to any particular art. I don't like to be personal, but I am supposed to be an electrical engineer. My consulting work ranges from sugar refining, boiler manufacture and high tension cables and electrical machinery and smokeless powder manufacturing. That is not because I was trained in any of these special subjects, barring the electrical engineering—and that I did mostly myself, but because I happened to have rather a broader fundamental scientific education and when these problems arose, instead of starting up somewhere in mid air, based upon the knowledge of the practice of that particular job, I said, "Why do you do so and so?" "Well, it has always been done that way." Then I begin in my solution of these problems down at the bottom, the fundamental scientific principles. Now, that is the whole problem, gentlemen, of this question of welding engineering and construction. You have got to have a foundation in the fundamental sciences relating to it.

MR. G. A. MOORE (*Detroit Range Boiler & Steel Barrel Co.*)—Mr. Swain mentioned in his discussion that he believed the next big step was to attack the problem on design, and then the other discussions brought out the need of an engineer trained in a university and grounded in mechanical science and electrical science and metallurgical and chemical science. The engineers that are at the structural steel fabrication end are structural engineers and they are trained in civil engineering. These courses stress, of course, the design of structural steel both as to main members and connections. I just wanted to bring to the attention of the professors that they should not overlook when they come to that problem—the fact that the structural engineer or the civil engineer should be particularly trained as to design. The reason I say that is in looking over these papers it seems to me, up to the present time at least, that they are giving this training mostly to mechanical engineers. The mechanical engineers who are finally to apply this knowledge will be structural engineers. I just want to make sure that when it comes to the point of having engineers that will know something about welding and designing of welded joints.

CHAIRMAN ADAMS.—I would like to point out that probably the reason for the present situation as regards this welding instruction to mechanical and structural engineers is due to the fact that up to the present time the structures with which civil engineers have been concerned have not been welded to any appre-

ciable extent. That is now coming in, and as soon as it does come in then the civil engineers will wake up and want a knowledge of welding.

MR. J. H. EDWARDS (*American Bridge Co.*).—I am one of these structural engineers. I have felt when I became connected with your organization that I would learn something. I don't think I ever attended a general meeting or committee meeting, but what I have learned something, and particularly I have learned today there is a great deal more attention being given to welding engineering in our educational institutions than I ever dreamt of. I have been out of touch with educational institutions as a student. I want to make just a few remarks on fundamental research—as long as our educational institutions show an interest, I think if they divide the problems, one institution to take one phase and not cover the whole field, they would not waste so much time and money, and would accomplish better results. The correlation of these efforts would result in a good deal more valuable results. Inasmuch as these educational institutions have shown so much interest and are so well prepared, I want to ask their cooperation with our structural steel research committee in developing some of the fundamental facts that we are after, and I hope when we ask them to do that, that they will be very responsive.

CHAIRMAN C. A. ADAMS (*Harvard Engineering School*).—I think you will get a very cordial response, Mr. Edwards. Cooperative research or cooperation in research is something that has received a very great deal of attention the last ten years. I gave up my teaching for two years; got leave of absence and devoted two years of my life to developing cooperative research as chairman of the division of engineering of the National Research Council. The National Research Council is organized for the particular purpose of cooperation in research, and they have committees in every field. Those committees are made up of the professors in these various institutions and they get together and that work is being divided up now. In a very large degree there is constant cooperation; nothing like what we would like ideally, but it has gone a long ways from what it was ten years ago.

MORNING SESSION
November 19

Discussion: Welding in a Gaseous Atmosphere

PRESIDENT F. M. FARMER (*Electrical Testing Laboratories*).—The meeting will please come to order. The subject for presentation this morning is one that will be of great interest to all of us because it involves a new development that promises to have far-reaching effects in our particular art. These new developments are of very great importance from a technical standpoint, but I feel that possibly they portend a development in our field of activ-

ity which is even more important. As I understand the process, it employs not only the electric arc but also gas, and you have, so to speak, the two processes in one. I hope that that means, portends and foretells an even closer union between the two large groups in our field.

The program indicated in the bulletin here will not be carried out exactly as it has not seemed possible to have a demonstration, but we hope we will have a fairly good substitute in the way of moving pictures, slides and, of course, the oral presentation. There are two speakers dealing with different phases of these subjects and I will ask Mr. Weinman of the Research Laboratory of the General Electric Company of Schenectady to present his comments first.

(Talk on "Welding in a Gaseous Atmosphere,"* illustrated by lantern slides and motion pictures by Mr. R. A. Weinman of the General Electric Company, Schenectady, N. Y.)

A MEMBER.—How long can you weld without adjusting the electrodes, or do they adjust themselves?

MR. R. A. WEINMAN (*General Electric Company*).—No, they don't adjust themselves, because to be able to do this would necessitate a too heavy torch. It only takes a second for a good operator to do it. He can weld as long as he would want to weld without stopping for a short time—at any rate without changing the electrode's position.

A MEMBER.—How long are the tungsten rods?

MR. R. A. WEINMAN (*General Electric Company*).—About 12 in. long originally.

A MEMBER.—How far can you burn them down before you change them?

MR. R. A. WEINMAN (*General Electric Company*).—Possibly to 2½ in.

A MEMBER.—We use the pieces, weld them together by the torch.

A MEMBER.—Is the open circuit voltage the same for any size of rod?

MR. R. A. WEINMAN (*General Electric Company*).—The open circuit voltage goes down with the size of the arc.

PRESIDENT F. M. FARMER (*Electrical Testing Laboratories*).—I think we will dispense with the discussion at this time and continue with the discussion after we have both papers. They both relate to the same subject and I am sure Mr. Weinman will answer questions later on.

MR. R. A. WEINMAN (*General Electric Company*).—Mr. Farmer, our company is not putting this equipment on the market right away, but it will shortly do so.

MR. F. M. FARMER (*Electrical Testing Company*).—It is still in the developmental stage?

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*Paper published in the Oct., 1926, issue, JOURNAL OF THE A. W. S.

MR. R. A. WEINMAN (*General Electric Company*).—Yes, it is still in the developmental stage.

PRESIDENT F. M. FARMER (*Electrical Testing Laboratories*). The next speaker, Mr. Alexander, is a scientist, and I understand had a good deal to do with the development of this process which is particularly interesting from the standpoint, I think, that Professor Adams mentioned yesterday, namely, that this development comes out of the field of pure science and pure physics; almost directly from the field of pure science to the field of applied science.

It is rather an unusual situation. Many of you I think have heard Mr. Alexander in some of our bureau meetings, and I am quite sure you will all appreciate his remarks. Mr. Alexander of the Thompson Research Laboratories of the General Electric Company.

MR. P. P. ALEXANDER (*General Electric Company*).—This subject on which I am going to speak is of general interest to all, I think, who are using arc process or any fusion welding. Mr. Weinman explained to you the principles of the atomic hydrogen process. In that process the energy is supplied by the electric arc, but the transmitting medium is the gas. So it could be compared with the gas process. In this way it has all the advantages of the gas process and certain characteristics of the arc process. The arc itself does not come in contact with the metal.

The process that has been developed in the Thompson Research Laboratory is essentially an arc process. In that process the arc is established between an ordinary carbon or metallic electrode and the plate to be welded. The only difference with the standard arc welding process is that the arc is protected or shielded from the atmospheric gases. In this way it is possible to protect the molten metal from the action of oxygen of the air and also to prevent other gaseous contamination of the molten iron.

This investigation originated from an entirely different consideration than that involved in the atomic hydrogen process. It was desired to improve the physical properties of arc deposited metal. The nitrogenation and the oxidation of metal had been studied by many investigators and is very well known. So the first thought was to protect the arc deposited metal from the action of oxygen and nitrogen. The first experiments were conducted with the arc burning in an atmosphere of carbon dioxide, then illuminating gas and super heated steam and finally in hydrogen. Welds produced in hydrogen gave a better result than in any other gas. But we did not stop at that stage. We used mixed gases. It was found it was not necessary in the shielded arc process to use pure hydrogen. It is sufficient that the shielding atmosphere contain a certain amount of hydrogen. The balance could be replaced by other gas, such as nitrogen, carbon dioxide and other neutral gases. In this way it is possible to use various gases which can be produced very readily and easily from the composi-

tion of certain organic materials or stored in liquefied compressed form. And also the arc is more stable in mixed gases. The open circuit voltage of the generator which is necessary with hydrogen, provided no special reactors are used, is about 110 volts. With the same generator having a resistance in series, if we dilute hydrogen with nitrogen or carbon monoxide, which will be water gas, the open circuit generator can be about the same as standard voltage, 60 or 70 volts. Even in pure hydrogen it is possible to use low voltage provided high induction is inserted in the welding surface. These are just a few words about the shielded arc process. I am not going into detail of describing this process, because the results of my investigation were published in the *General Electric Review*, and any one of you who is interested may consult that.

I will proceed with my paper. This paper* will be published in the next journal of the American Society, and as it is not now published I might just read a little bit of it.

MR. J. C. LINCOLN (*Lincoln Electric Company*).—Mr. Alexander stated that under the boiling point of iron the gases in all molten metal were driven off, which sounds reasonable; and that at the freezing point of iron very large quantities of gases are driven off. He stated that somewhere between freezing point and the boiling point that the absorption of gas was very rapid, and the absorption probably somewhere between freezing and boiling point was several times the absorption at any other point. I would like to know the evidence on what that statement is based.

MR. P. P. ALEXANDER (*General Electric Company*).—To determine exact temperature at which the absorption of gases by molten metal occurs is exceedingly difficult.

MR. J. C. LINCOLN (*Lincoln Electrical Company*).—I thought it was impossible.

MR. P. P. ALEXANDER (*General Electric Company*).—It is almost impossible, but I will describe to you how this was determined by one of the investigators, I think in England, by determining the gas absorption of hydrogen by molten copper. He was melting small copper ingots in an electric furnace and the temperature of the furnace was kept constant so that the molten metal was kept for a long time at that temperature and exposed to the gas. Then at a given moment the crucible containing that molten metal was dropped down from the furnace to the cooling chamber, and almost instantly the surface of the ingot was solidified. That, of course, trapped all the gases inside of the ingot, which formed numerous blow holes in the ingot. After cooling the ingot was cut and the volume of those blow holes and gas pockets were determined. The furnace he was using, I believe, was the usual electric furnace, and the crucible containing copper was placed right in the middle. Then at a given moment the crucible was withdrawn very rapidly, somewhere down in the cooling chamber and

*Paper published in this issue of JOURNAL.

solidified. He repeated the experiment at various temperatures and he found that the maximum volume of blow holes was somewhere between boiling and melting point. The volume of those blow holes dropped very gradually here, and then very abruptly to the boiling point.

MR. J. C. LINCOLN (*Lincoln Electric Company*).—These experiments were with hydrogen?

MR. ALEXANDER.—With hydrogen.

MR. J. C. LINCOLN (*Lincoln Electric Company*).—Because the gases act that way, is that an inference or is that based on evidence?

MR. P. P. ALEXANDER (*General Electric Company*).—The experimental data is very small, but I simply assume that other gases will follow approximately the same procedure. Of course hydrogen is more soluble than other gas in copper or steel or iron. One cubic foot per molten steel evolves on solidification 160 cu. ft. of gases at that temperature. If you reduce the volume of these gases to the normal temperature, the volume will be 27 cu. ft. per molten in foot of steel.

MR. J. C. LINCOLN (*Lincoln Electric Company*).—These gases are driven off in the solidification in ordinary open hearth steel?

MR. P. P. ALEXANDER (*General Electric Company*).—Yes, sir.

ANOTHER MEMBER.—In depositing high carbon steel such as self-hardening steel containing chromium, and tool steel, by metallic arc process, numerous blow holes, as you described, were experienced. Now, in melting the same steels with the metallic arc process and a heavy layer of (flux) in a small crucible playing the arc rod sufficiently until the whole mass became molten, the metal of course dropping from the electrode, but at the same time raising the temperature of the small crucible and then allowing it to cool with a free layer of flux on top to prevent any oxygen reaching it and solidifying, it was more easily welded than the original metal. But when trying to deposit in layers, like on dies, and so forth, it was not possible to set a good weld. What occurs to me is—the crucible had to cool; the gases no doubt were absorbed, but the crucible while it cooled slowly, apparently was free from these gas pockets or blow holes. Now the action in both cases would be the same. In the one case there would be more blow holes and then when deposited on a solid piece of metal and cooled rapidly there would be no blow holes. I was just wondering what reaction was taking place.

MR. P. P. ALEXANDER (*General Electric Company*).—As I understand, when the metal is in a crucible—

A MEMBER.—It was not always the mass in a crucible. We just simply used a slab and had a small pool and as long as the metal was entirely heated in a solid mass it would solidify free from blow holes and comparatively free from contamination; but in the deposit on another piece of metal of a similar kind, it was very difficult to keep it free from blow holes.

MR. P. P. ALEXANDER (*General Electric Company*).—It seems to me simply a matter of giving time for the gases to escape. If you heat ordinary steel or crucible steel and let it solidify too rapidly, it will form blow holes.

I think it depends on the exceedingly short time in which the gases in the molten steel are expelled from the molten steel. A certain amount of gas is in the molten state; in a solid state not much will be left. This change occurs in a very short time unless you find some means of retarding it.

A MEMBER.—In removing the flux on top there would be a large percentage of blow holes even in the ingot. That is the mystery that has puzzled me more or less. If there were fluxes in the pool covering the pool more or less, it would be entirely free from blow holes. If cut through you could see near the upper surface a zone of one-sixteenth of an inch almost just like a layer of small blow holes giving it a crystalline effect.

MR. P. P. ALEXANDER (*General Electric Company*).—The amount of heat which is produced by oxidation of a top layer is sufficient to raise the temperature by several hundred degrees provided that amount of heat is absorbed, like in a weld, by a very thin top layer. If you have a large ingot which solidifies, that heat will be distributed, conducted through the whole ingot, through the whole mass, and then that amount of heat will not be sufficient. Then you have to provide some additional method of keeping that surface clean. Well, if you cover it completely with fluxes to start with, it will prevent largely radiation from the top layer into the atmosphere so it will retard the evolution of heat. Also certain fluxes will generate a certain amount of heat.

ANOTHER MEMBER.—I wonder if any member here has tried or carried out experiments in the summer time and the winter time with bare electrodes both on steel and on tool steel. We have been carrying out some experiments and we find in the winter time with tool steels—it is best to apply heat in the form of illuminating gas. We find in the winter time we get a very, very large percentage of blow holes; in the summer time they nearly all disappear. In the winter time we use illuminating gas to retard the cooling.

A MEMBER.—We have had the very same thing. We maintain a sort of preheating process to a dull red.

MR. P. P. ALEXANDER (*General Electric Company*).—Was that done by the arc process?

A MEMBER.—By the arc process.

MR. P. P. ALEXANDER (*General Electric Company*).—It seems to me that difference in temperature in winter and in summer is not sufficient to produce marked difference on the speed of solidification of the metal; but perhaps some other factors may affect it. Water condenses on the electrodes, and the electrodes in the winter time are liable to be covered with moisture and of course that moisture

vaporizes and forms oxygen and hydrogen. Hydrogen will make the arc unstable. Another thing, hydrogen may be absorbed by molten metal more than in the summer time. The humidity of the air affects the Bessemer process. The amount of gas evolved by Bessemer steel during the solidification in summer time is something like 22 cubic feet per one foot, or 75 for steel. In the summer time or in very damp weather the amount of gas is raised from 23 or 22 to 27 cu. ft. per foot. So there is a considerable difference in the amount of gas.

MR. J. A. TOLEIK (*American Can Company*).—Have microphotographs been made to check up the deposited metal with the original, after it is deposited and before it is deposited with the shielded arc process so as to know what, if any, changes were taking place in the metal deposited?

MR. P. P. ALEXANDER (*General Electric Company*).—Yes, we usually take a large number of photographs on every sample.

MR. J. A. TOLIEK (*American Can Company*).—What has been your experience? We have done quite a bit of that ourselves and made innumerable photographs of one-thousand diameter magnification and have at least shown marked differences in the characteristics of the material as indicated by the micro-photographs. Some of them seem to have a very close grained structure after deposit, and sometimes welds have large grained structure; in fact the grain structure might have a ratio of 50 to 1 differences as they appear on the photographs.

MR. P. P. ALEXANDER (*General Electric Company*).—I think it depends on the speed of solidification—the grain growth. If you use a very powerful arc and the travel is very slow and the deposit of metal is pure iron, without any doubt the grain growth will be very pronounced.

A MEMBER.—I would like to ask Mr. Weinman just one question. In welding alloys, non-ferrous alloys, as he showed in the slide, what variation is there in the analysis after the weld is made? Is there any change in the metal at all, and in the qualities of the finished metal, alchemite metal? Will it be acid resisting after the weld is made, the same as the original metal?

MR. R. A. WEINMAN (*General Electric Company*).—Alchemite I know has very little change; in fact I don't know of any change. You all know what the average person does when he analyzes that metal. No two men will have exactly the same strip of metal. After examination of the welded alchemite I can see no difference from the original piece.

A MEMBER.—Is the atomic arc suitable for welding aluminum and its alloys?

MR. R. A. WEINMAN (*General Electric Company*).—Yes.

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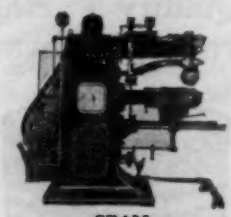

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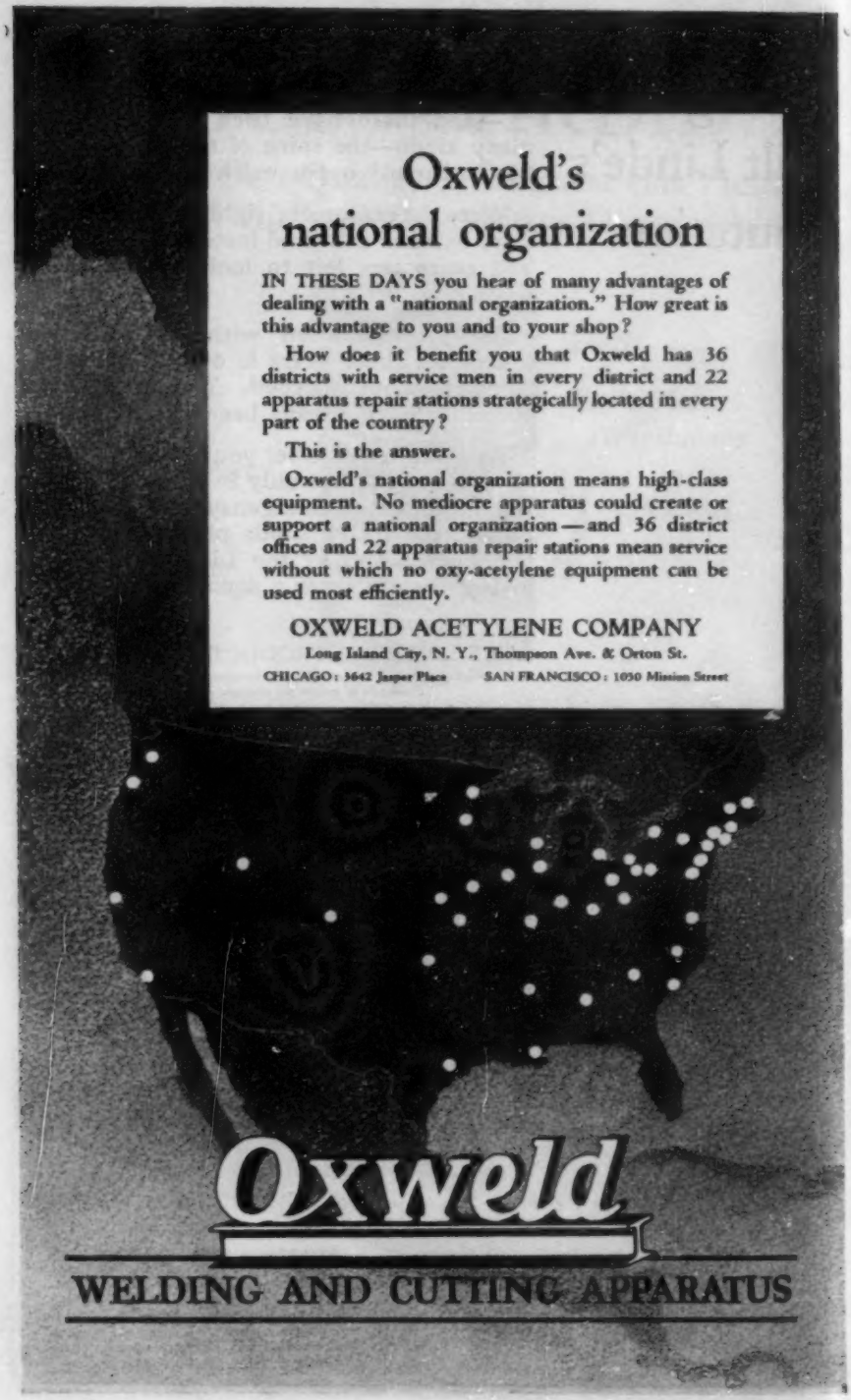

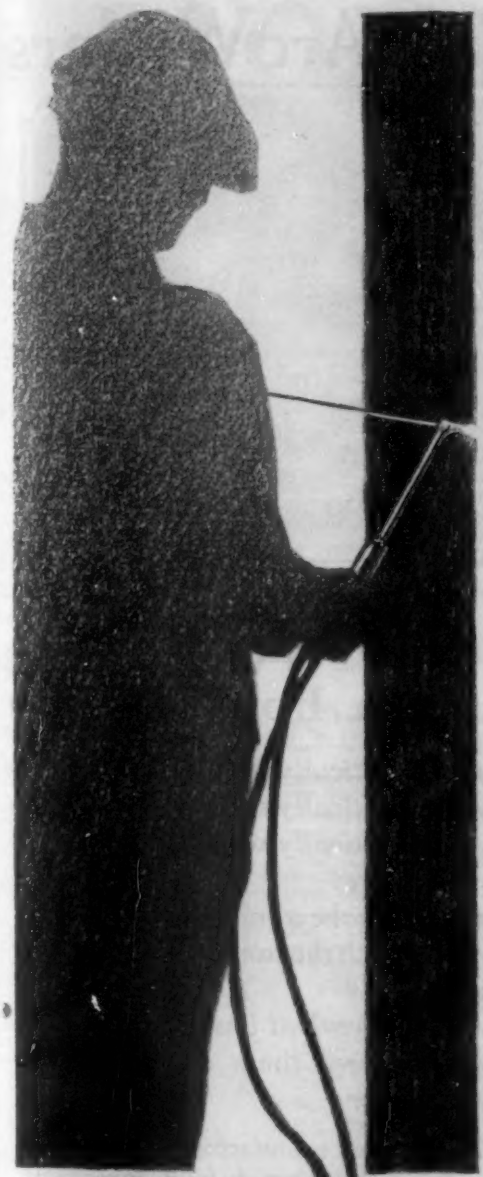

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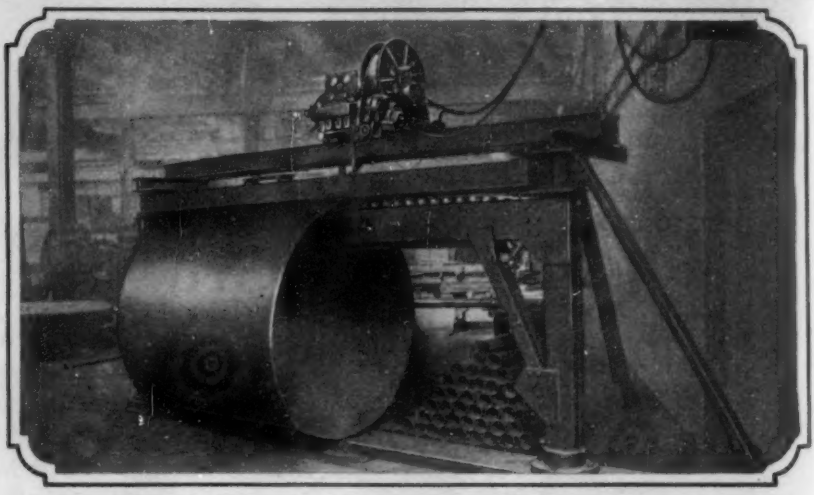

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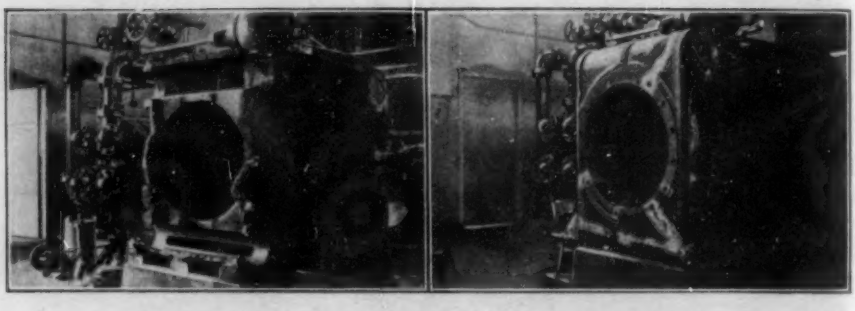

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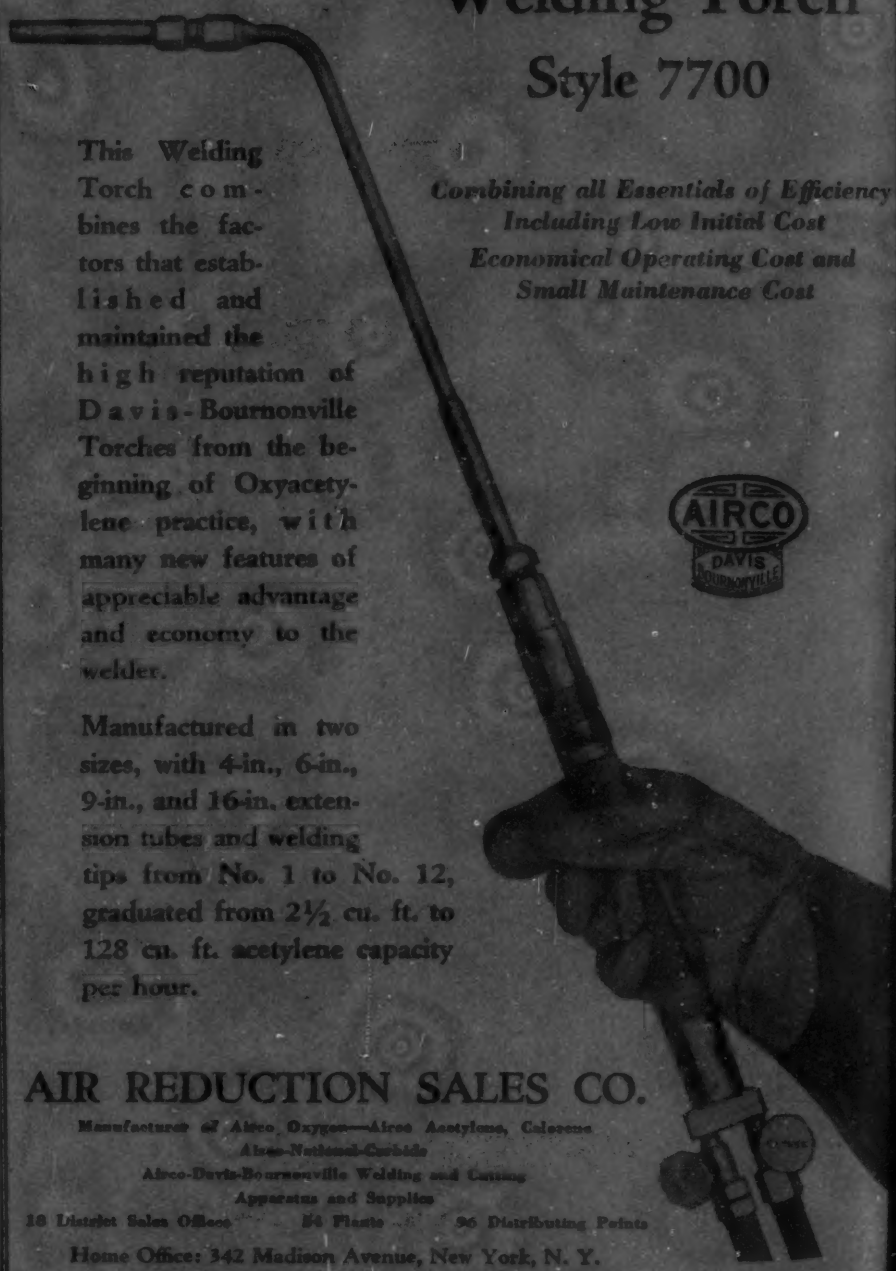

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